MINUTES OF PROCEEDINGS

OF THE

ROYAL ARTILLERY INSTITUTION.

VOLUME III.

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LIST OF PLATES.

REPORT

OF

ORDNANCE SELECT COMMITTEE.

No. 1484, March 7, 1861.

MANTLETS FOR THE PROTECTION OF ARTILLERYMEN FROM AN ENEMY'S RIFLEMEN.

CORRIGENDA.

PAGE
18, extract, 5th line from bottom, *for* "ou" *read* "on."
22, line 4 from top, *after* "is" *dele* comma.
25, line 15 from top, *for* "correspondes" *read* "corresponds;" and for "*mirit*" read "*merit*."
30, line 23 from top, *for* "spot" *read* "spots."
37, first line, *for* "rounds" *read* "weights."
— last line but one, *for* "top" *read* "tops."
40, round 34, *for* "S" *read* "Sc."
42, round 5, insert tabular information for that round.
47, line 11 from top, *for* "batteries. The &c." *read* "batteries,—the &c."

consideration, they are not yet in a position to recommend any one construction for general adoption.

2. The Committee referred in their former Report, No. 800, to the records of previous inquiries into this subject, shewing that many varieties of mantlet have been under consideration, none of which were found at the time to meet the requirements of the service; and numerous experiments have been made at Woolwich and Chatham, but more particularly at the latter place, to test the resistance of different constructions. The early inquiries, however, are now of little value; for the whole question has assumed a different aspect since the universal introduction of rifled small arms, whose penetration, as compared with that of the smooth-bored weapon in use previous to 1851, is as 10·6 to 7·5 at 30 yards; and at greater distances is in a much higher proportion. And this great penetrative power is not the only difficulty: it is perfectly possible to make a mantlet not inconvenient for use, which can keep out rifle musket bullets at 25 yards; unfortunately

such mantlets not only give no security against cannon shot, but they also, as will be shewn below, add in some cases considerably to its destructive effects; and until a material can be found which shall combine with manageability the property of stopping small-arm projectiles without breaking up itself or breaking the projectile into splinters, when struck by a cannon shot, the Committee believe that the use of mantlets for embrasures must be confined to exceptional situations.

3. ROPE MANTLETS.—These contrivances were brought into notice by their employment in the defence of Sebastopol, 1855. The specimens then tried weighed from 4 cwt. to 6 cwt., or from 17 lbs. to 27·5 lbs. per square foot. The Committee reported on 27th September, 1857, No. 1209, as the result of their experiments, that it required five thicknesses of 4·5-inch rope to resist a bullet at 50 yards: such a mantlet would be 7·5 inches thick, and weighs 27·5 lbs. to the square foot. This report was printed, with the sanction of the Secretary of State, in the "Occasional Papers" of the Royal Artillery Institution, Vol. II. p. 3, with a detail of the experiments; and was also circulated extensively in print for the information of naval officers and others concerned.

The Committee have not thought it necessary to enter any further into the question. The value and efficiency of rope mantlets is undeniable: their cumbrousness is the only obstacle to their more frequent use. The Committee have learned from a memo. of the Deputy Inspector General of Fortifications, dated 13th October, 1859, that a demand has been made by the Royal Artillery at Malta for rope mantlets to be kept in store, and for the means of suspension to be applied to the parapets; and they concur in opinion with that officer that a pattern should be established, but one shewing the quality and mode of manufacture rather than the form, which may vary.

4. IRON-PLATE MANTLETS.—Experiments at Chatham in 1858 established the fact that homogeneous iron 0·25-inch thick will resist rifle bullets at less than 50 yds. distance; and since the receipt of Lord Herbert's instructions, dated 26th August 1859, the attention of the Committee has been chiefly directed to this material, with a view to discovering the minimum thickness necessary, and the best quality. In the first instance experiments were made with rolled iron plates furnished by Messrs Thorneycroft of Wolverhampton, 4 ft. by 2 ft. in dimensions, 0·25 in. thick, weight 10 lb. 14 oz. per square foot. One of these resisted rifle bullets fired at 10 yds., but others were penetrated at 50 yds.: see Report No. 800. Four plates of the same thickness, but of less dimensions, viz. 2 ft. by 2 ft., fitted with handles for convenience of lifting them, and provided with screw or rivet holes, by which any number could be combined, were next tried: see the Report above quoted, No. 800, 12-5-60. The quality of these plates were not found to be uniform; some parts resisted the bullets at 10 yds.; others did not resist, and the balls penetrated.

5. The Committee then obtained permission to try homogeneous iron furnished by Messrs Shortridge and Howell of Manchester. Twelve mantlets were provided, each 2 ft. by 2 ft., 0·25 in. thick, and weighing 10 lbs. per square foot. They were fitted like the last with handles and screw holes,

with the intention that each plate should be a unit capable of combination with others. These plates, in accordance with the Committee's recommendation, were tried at Chatham in August, 1860. They were found proof against bullets fired by the Lancaster carbines of the Royal Engineers at 50 yds., and subsequently against Enfield rifle bullets at the same distance; but on suspending them in front of an embrasure many pieces of the bullets, some large, but the greater part small, found their way between them, and between the plates and the parapet, glancing off the plates as they swung from the blow. These splinters were sufficient, in the opinion of the officer who conducted the experiment, Major Lovell, R.E., to have made the part of the battery immediately adjoining quite untenable. On inspection of a canvas screen set up at 5 ft. to the left, to catch the splinters, it appeared that scarcely any of them diverged more than 2 ft. at that distance; consequently, men standing round the gun at a greater distance from the parapet would have been safe, and if there were a traverse adjoining, the next gun detachment would also be safe. The result rather points to the necessity of a mode of suspension which will not permit the splinters to penetrate, or the necessity of a lateral projection to catch them, than to a rejection of iron plates on this account.

Another mantlet of the same material, furnished by Captain W. L. Yonge, R.A., D.-A.-A.-Gen., was tried at Woolwich in July, 1860. It was 4 ft. by 2 ft., and $\frac{1}{4}$ in. thick; weight 100 lbs. 6 oz., or $12\frac{1}{2}$ lbs. per square foot. It was perfectly bullet-proof at 10 yds.; but on repeating the experiment with a plate of $\frac{3}{16}$th inch, weighing 71 lbs. 12 oz., or 9 lbs. per square foot, it was penetrated at 25 yds., shewing that nothing less than $\frac{1}{4}$ in. homogeneous iron will give the complete protection desired.

6. PRICE'S CASE-HARDENED WROUGHT IRON.—Mr G. Price of Wolverhampton called the attention of the Committee in May 1860 to the effect of case-hardening on iron, and forwarded a plate $\frac{1}{2}$ in. thick as a sample. His object, however, was rather to form the armour plates of ships of this material than mantlets. On trial this $\frac{1}{2}$ in. plate proved perfectly bullet-proof, and was scarcely indented at 10 yds., but various fine cracks gave reason to suppose that if reduced to the same weight and thickness as the other irons employed it would have had less resistance; and this view being sustained by mechanical tests in the Royal Gun Factories the material was not recommended.

MILLARD'S MANTLETS. See Article 14.

7. Captain W. L. Yonge, R.A., D.-A.-A.-Gen., forwarded in December, 1859, five plates of tempered steel made by Bessemer's process, each 2 ft. by 4 ft., and of various thicknesses, from 0·0625, or $\frac{1}{16}$th inch, to 0·10, or $\frac{1}{10}$th inch, and weighing from 3·5 lbs. to 4·5 lbs. per square foot. He forwarded at the same time an equal number of plates of annealed steel by the same makers, varying in thickness from 0·05 in. ($\frac{1}{20}$th) to 0·125 in. ($\frac{1}{8}$th); and in weight from 3·6 lbs. to 4·75 lbs. per square foot. His intention was to combine these thin plates in pairs, with an interval between them, and they were tested with the following results:—

Tempered Steel.			Annealed Steel.		
No.	Nominal thickness.	Weight.	No.	Nominal thickness.	Weight.
	inch.	lbs. oz.		inch.	lbs. oz.
1	$\frac{1}{10}$	36 8	6	$\frac{1}{8}$	38 0
2	$\frac{1}{16}$	29 0	7	$\frac{1}{10}$	33 0
3	$\frac{1}{16}$	28 8	8	$\frac{1}{20}$	29 0
4	$\frac{1}{10}$	32 14	9	$\frac{1}{10}$	35 8
5	$\frac{1}{8}$	39 12	10	$\frac{1}{12}$	27 4

Nos. 1, 2, 3, taken singly, were each penetrated at 50 yds.

Nos. 1 and 3, weighing together 8·12 lbs. per square foot, were then placed together on the ground, upright, resting against the stand; four shots were fired at them, three of which passed through first and dinted second, and one hit an old shot mark and passed through both plates.

Nos. 2 and 3, weighing together 7·19 lbs. per square foot, were then placed behind each other, leaving an interval of 1 in. at the top, gradually increasing to 2 in. at bottom; five shots were fired at them, three of which passed through first and dinted second; one passed through both, and one lodged in first and cracked the second.

Nos. 6, 7, and 8, weighing together 12·50 lbs. per square foot, were placed upright in a line against the stand on the ground; three shots were fired at them at 50 yds. distance; all passed through.

Nos. 6 and 7, weighing together 8·89 lbs. per square foot, were then placed so as to overlap No. 8; four shots were fired at them; all passed through the first and dinted second.

The stand was moved up to 25 yds., when three more shots were fired; two passed through first, indented and cracked the second considerably.

The stand was moved up to 10 yds.; five more shots were fired at them, when three passed through both, and two through first and dinted second plate.

Nos. 9 and 10, weighing together 7·84 lbs. per square foot, were placed upright in a line against a stand on the ground; two shots were fired at them at 50 yds.; both passed through.

No. 9, weighing 4·44 lbs. per square foot, was placed in front of No. 10, touching at top, but gradually separating downwards; five shots were fired at them, three of which passed through first and dinted second, and two passed through first and lodged in second.

No. 10, weighing 3·41 lbs. per square foot, was then placed in front of No. 9, reversing the order; five shots were fired at them; four of which passed through first and lodged in second, and one passed through first and dinted second.

Nos. 10 and 4, weighing together 7·52 lbs. per square foot, were then placed behind each other, leaving an interval of about 1 in. No. 10 in front, five shots were fired at them; all passed through first; two lodged in second; two dinted second, and one cracked second.

Nos. 4 and 5, weighing together 9·08 lbs. per square foot, were placed upright, in a line, leaning against a stand on the ground; two shots were fired at them; both passed through them.

No. 5, weighing 4·97 lbs. per square foot, was placed behind No. 4, leaving an interval of about an inch; five shots were fired at them, four of which passed through first and slightly dinted second, and one passed through first and broke second at the top of plate.

No. 4, weighing 4·11 lbs. per square foot, was then placed in front of No. 5; five shots were fired at them, four of which passed through first and lodged in second.

No. 5, weighing 4·97 lbs. per square foot, was then placed in front of No. 4, 4½ ft. apart, both mantlets leaning against a stand; five shots were fired at them; all passed through first and slightly dinted second.

No. 9, weighing 4·44 lbs. per square foot, was then placed in front of No. 10, 4½ ft. apart, leaning against a stand; two shots were fired at them; both passed through first and dinted second.

No. 10, weighing 3·41 lbs. per square foot, was placed in front of No. 9, 4½ ft. apart, leaning against a stand; one shot was fired at them, which passed through first and lodged in second.

No. 9 was taken away, and two more shots were fired at No. 10, one of which passed through it, and hit the target very hard; the other passed through the plate and penetrated the leg of wooden stand.

8. The result shewed a decided superiority of the annealed steel over the tempered steel, and gave encouragement to the principle of construction adopted.

Captain Yonge then submitted a mantlet composed of two ⅛th inch plates of homogeneous iron secured by bolts and nuts, with a space of 1¼ in. between them. The weight was 13 lbs. per square foot. It was fired at July 6th, and proved perfectly bullet-proof at 10 yds. The bullets passed through the first plate and slightly indented the second, but did not in any case fracture or penetrate it.

The experiment was repeated July 13th, with interval of the plates reduced to ¼ in., with the same results as to non-penetration of the second plate, but it was much more deeply indented by the bullets which penetrated the first plate.

The experiment was repeated in October, with a mantlet weighing 10½ lbs. per square foot, and composed of thinner plates, viz. one of $\frac{1}{16}$th inch, the other rather more than ⅛th inch (about 0·14 in.), they were restored to the original interval of 1¼ inch, and proved perfectly shot-proof at 10 yds.

9. The foregoing trials having sufficiently established the resisting powers of the several materials referred to, the Committee took steps to ascertain their behaviour when struck by cannon shot.

With this view the ¼ in. homogeneous iron mantlet of 4 ft. by 2½ ft., submitted by Captain Yonge, No. 23 of the accompanying list, another mantlet, No. 2, of Thorneycroft's steel iron, and one of Captain Yonge's double mantlets, No. 26 in the general list, were fired at with segment shells from an Armstrong 12-pr., at 400 yds., and solid shot from a smooth-

bore 32-pr. at the same distance; each mantlet was struck twice with either projectiles, targets being placed 5 yds. in rear to catch the splinters.

Description of Mantlet.	Effect of two 12-pr. segment Shells or solid Shot at 400 yds.	Effect of two solid 32-pr. Shot at 400 yds.
Homogeneous iron mantlet, 4 ft. × $2\frac{1}{2}$ ft., and $\frac{1}{4}$ in. thick; weight 100 lbs., or 10 lbs. per square foot.	The two shells passed through, making a circular hole burred outwards, but carrying away very little of the plate. The shells themselves, however, were broken up, and 42 splinters struck the targets, nearly all within a circle of 4 ft. diameter. One Armstrong 12-pr. solid shot subsequently passed through the same mantlet, and a second cut the edge. They did not occasion any splinters.	Mantlets much torn, large irregular shot holes formed, and eleven splinters carried into the targets.

Description of Mantlet.	Effect of two 12-pr. segment Shells or solid Shot at 400 yds.	Effect of two solid 32-pr. Shot at 400 yds.
"Steel iron" mantlet, 4 ft. × 2 ft., $\frac{1}{4}$-inch thick, supplied by Thorneycroft; weight 84 lbs., or $10\frac{1}{2}$ lbs. per square foot.	Segment shells not tried, it being proved by the previous experiment that they break up. Armstrong 12-pr. solid shot passed through without causing any splinters.	Large shot holes; twenty-seven splinters carried into the targets, leaving less torn iron round the edges than in the previous experiments.
Captain Yonge's double mantlet plates, $\frac{1}{8}$ and $\frac{1}{12}$ inch homogeneous iron, $1\frac{1}{4}$-inch apart; weight 86 lbs., or 8·6 lbs. to the square foot.	Segment shells not tried. 12-pr. Armstrong shot passed through without causing any splinters.	The mantlet was thrice struck, one shot being a slight graze; both the others also broke the edge. There were seven splinters in the targets. The mantlet had been previously fired at with a 9-pr. at 20 yds., which formed a large hole.

10. The Committee are of opinion, from the foregoing results, that thin iron mantlets of the qualities tried are not adapted for closing the embrasures of guns liable to be attacked directly or replied to by artillery. They may perhaps be advantageously applied to embrasures in elevated situations, or others where, from the nature of the ground in their front, guns are little likely to be brought against them; and in such case shutters of homogeneous iron $\frac{1}{4}$ in. thick would appear, on the whole, preferable to the double-plate mantlet in simplicity and durability, the weight being nearly the same, about 10 lbs. per square foot. Their size, form, and mode of suspension must vary with the form of the embrasure or opening; but in any case they should be so attached as not to permit that entry of splinters observed at Chatham.

Should any tougher quality of iron be hereafter made, that will resist bullets but permit the passage of cannon shot and shells without splintering itself or breaking up the shells, the problem will have been completely solved. A careful system of proof will be necessary when any iron plates are employed, as they differ much in power of resistance.

11. For siege works and other situations much under artillery fire, the Committee incline to the belief that a non-resisting screen or curtain, which

simply hides the interior of the work, is preferable to a mantlet. An early and interesting instance of the employment of this expedient will be found in the history of the defence of Gibraltar in 1782.

12. Admiral Sir G. R. Sartorious has submitted to the Committee a number of mantlets on what he terms the *jalousie* principle. They consist of plates of iron 3 ins. wide, and of any convenient length. The specimens produced have varied from 18 ins. to 30 ins. in length, and from $\frac{1}{12}$th to $\frac{1}{4}$ in. in thickness. These plates are riveted to raw hide, or connected with iron hinges at intervals, but so as to overlap each other, and have been tried in rolled steel and homogeneous iron. One defect was common to the whole of them; some of the bullets or splinters of bullets invariably passed through the joints, notwithstanding the overlap; the iron hinges also gave way very soon, as did the narrow leather thongs or strips of hide, permitting the plates to separate; but this defect was not observed when they were riveted to entire hides.

The following is an abstract of the experiments:—

Thickness of Plates.	Material.	Result.
inch.		
$\frac{1}{12}$	Homogeneous iron, riveted to cow-hide; 5 lbs. 9 oz. to square foot.	Plates pierced at 50 yds.
$\frac{1}{10}$	Ditto; 5 lbs. 9 oz. to square foot.	Plates pierced at 50 yds.
$\frac{1}{8}$	Rolled steel, ditto; 6 lbs. 15 oz. to square foot.	Proof at 50 yds.; one bullet penetrated at 25 yds.
$\frac{1}{8}$	Homogeneous iron, hinged with iron straps; 6 lbs. to square foot. These plates were curved to the ogee form.	The hinges gave way, but the mantlet was bullet proof at 10 yards.
$\frac{1}{8}$	Homogeneous iron, hinged with iron strap, curved as above; 7 lbs. 10 oz. to square foot.	Not proof at 75 yards. The hinges gave way after twenty rounds.
$\frac{1}{8}$	Homogeneous iron, riveted to two strips of cowhide; weight 5 lbs. 10 oz. to square foot; four plates ogee; 5 plain.	Not proof at 75 yds.
$\frac{1}{4}$	Rolled steel, riveted on cowhide; weight 12 lbs. 2 oz. per square foot.	Bullet-proof at 10 yds.

The Committee reported on 2nd February 1861, Report No. 1412, that, in their opinion, the *jalousie* construction is unsuitable. There is a great liability, however the plates are attached, for the bullets to force themselves through at the junctions; if they are attached to jointed iron straps, these get broken after a few blows; if to hide, its tendency to stretch in wet weather or continued damp gradually opens the joints; and their rigidity at other times deprives the structure of any special advantage arising from the nominal flexibility of this species of construction.

13. At the suggestion of the Inspector-General of Fortifications, a trial was given to a screen of $1\frac{1}{2}$-in. wire rope in two thicknesses, disposed so as to cross each other at right angles; each rope was composed of 6 strands, each of six galvanized iron wire of about 0·055 in. in diameter. It was very heavy, namely 25 lbs. to the square foot, and was penetrated readily at 50 yds., several ropes being cut asunder. Samples of a strong wire network

have also been submitted, but the Committee are of opinion that no fabric of this kind will equal plates of the best iron in resistance, while its splinters will be much more dangerous.

14. The Superintendent, Royal Carriage Department, submitted a mantlet proposed by Mr Millard of that department, which is properly referable to the class of plate mantlets.

It was composed of two large plates of homogeneous iron 0·30 in. thick; the upper one suspended on a fixed joint, so as only to yield enough to allow the muzzle, on recoil, to clear itself; the lower one hung like a window-sash with counterpoises, in such a manner as to rise freely, and close the opening left on the recoil of the gun. As it is perfectly established that 0·30 in. iron will resist musket balls, the question to which the Committee have directed their attention has been the practical convenience of this arrangement, and they have to report, that there is no difficulty in working this mantlet, nor does it seem difficult to apply to it any masonry embrasure. Its use in any particular locality will depend upon the probability of its being exposed to artillery fire. Its advantages over shutters suspended in other ways, or other applications of thin iron plates, will turn chiefly on the construction and position of the embrasures, and appears to be rather a question for the Inspector-General of Fortifications than for this Committee.

15. Captain Beaumont, Royal Engineers, has proposed a mode of protecting casemated embrasures in new works by a strong shutter of 2½ inch iron, working like a sliding door in recesses left in the masonry. This thickness is proof against grape-shot as well as musketry. Having recently reported on this plan, Report No. 1456, 23rd February 1861, the Committee have only to remark that it is open to the general objections raised in the foregoing part of this Report to iron as a material, when not capable of resisting cannon shot; but in other respects appears a convenient arrangement, especially if constructed to be raised like a portcullis into a vertical groove or recess, which cannot easily be choked up. Its superiority over other arrangements in any particular case will turn chiefly on questions of construction and cost.

An Abstract of the experiments is appended.

J. St GEORGE.

LIST OF MANTLETS WHICH HAVE BEEN TRIED BY THE ORDNANCE SELECT COMMITTEE SINCE OCTOBER 1859.

No.	By whom proposed.	Description.	Thickness.	Total weight.	Weight per sq. ft.	When tried.	Result.
			in.	lbs. oz.	lbs. oz.	1859.	
1	Col. Robinson, R.E.	Thorneycroft's rolled iron, 4′×2′...	$\frac{1}{4}$	87 0	10 14	10 Oct.	Three shots passed through the plate at 50 yds., and at 75 yds. it was considerably indented.
2	do................	Thorneycroft's steel iron, 4′×2′ ...	$\frac{1}{4}$	84 0	10 8	1 Nov.	None of the bullets passed through the plate at 50 and 25 yards, but the plate was indented and cracked considerably.
3	Admiral Sartorius, R.N.	Rolled steel plain plates, 2′6″×3″, riveted on cowhide.	$\frac{1}{8}$	52 0	6 15	10 Nov.	One shot passed through a plate at 25 yards; at 50 yards the plates were considerably indented and cracked, and the bullets passed between the joints.
4	do................	do..................................	$\frac{1}{4}$	91 0	12 $2\frac{2}{15}$	"	None of the bullets passed through a plate at 50, 25, or 10 yards distance; the plates were considerably indented; the bullets passed between the joints.
5	Captain Yonge, R.A.	Tempered steel	$\frac{1}{10}$	36 0	4 8	6 Dec.	None of these plates are bullet proof at 50 yards. Nos 5 and 7 plates, placed together, bullet passed through first and dented second, and one hit an old shot mark and passed through both plates.
6	do................	do..................................	$\frac{1}{16}$	29 0	4 10	"	
7	do................	do..................................	$\frac{1}{16}$	28 0	3 8	"	
8	do................	Annealed steel	$\frac{1}{8}$	38 0	4 12	"	Nos. 8 and 9 plates placed so as to overlap No. 10: bullets passed through first, and dented second, and the same result at 25 yards distance.
9	do................	do..................................	$\frac{1}{16}$	33 0	4 2	"	
10	do................	do..................................	$\frac{1}{20}$	29 0	3 10	"	
11	do................	do..................................	$\frac{1}{10}$	38 8	4 13	8 Dec.	No. 11 plate placed in front of 12, gradually separating downwards; bullets passed through first and dented second.
12	do................	do..................................	$\frac{1}{12}$	27 4	3 $6\frac{1}{2}$	"	
13	do................	Tempered steel	$\frac{1}{10}$	32 14	4 $1\frac{3}{4}$	"	No. 13 plate placed behind 14, leaving an interval of about an inch; bullets passed through first and slightly dented second.
14	do................	do, 4′×2′ each	$\frac{1}{8}$	39 12	4 $15\frac{1}{2}$	"	
						1860.	
15	Admiral Sartorius, R.N.	13 homogeneous plain iron plates, 2′6″×3″, overlapping half-an-inch, riveted to cowhide.	$\frac{1}{12}$	41 12	5 9	5 Jan.	Not bullet-proof at 50 yards; the metal was too highly tempered, and only successfully resisted the bullet when the overlapping joints were fairly hit.
16	do................	14 do	$\frac{1}{10}$	41 8	5 $8\frac{8}{15}$	23 Feb.	Not bullet proof at 50 yards; two shots passed through, and two hit the overlapping, which did not penetrate.
17	Col. Robinson, R.E.	Thorneycroft's iron in two plates, 2′×2′ each, joined in the centre to a piece of wood.	$\frac{3}{16}$	85 10	10 $11\frac{2}{8}$	6 Mar.	Not bullet-proof at 25 yards; one shot passed through, and one hit an old mark and passed through with great force; the plate was considerably cracked and indented; at 10 yards, four shots passed through.
18	do......................	do, screwed together in the centre	$\frac{3}{16}$	85 13	10 $11\frac{5}{8}$	30 Mar.	Not bullet-proof at 25 yards; three shots passed through, and three nearly through; plate indented and cracked considerably. At 10 yards, six shots passed through out of ten.

LIST OF MANTLETS, &c.—*Continued.*

No.	By whom proposed.	Description.	Thickness.	Total Weight.	Weight. per sq. foot.	When tried.	Result.
			in.	lbs. oz.	lbs. oz.	1860.	
19	Admiral Sartorius, R.N.	3 homogeneous iron plates, ogee, $1'6\frac{1}{4}'' \times 3''$, hinged on jalousie fashion, overlapping.	$\frac{1}{8}$	6 13	6 0	4 June.	Bullet-proof from 75 down to 10 yds.; not one passed through; the plates were considerably indented; the jalousie part was a failure; the hinges gave way.
20	do.	20 homogeneous iron plates, ogee, $2'6'' \times 3''$, overlapping half-an-inch, hinged on jealousie fashion.	$\frac{1}{8}$	73 6	7 10	6 July.	Not bullet-proof at 75 yds.; resisted when hit fair on the flaps, but when near the joint forced its way through. The hinges gave way after 20 rounds.
21	Captain Yonge, R.A......	Homogeneous iron, two plates, $4' \times 2'6''$ and $1\frac{1}{4}$ in. apart.	$\frac{1}{8}$	105 12	10 $9\frac{2}{10}$	,,	Bullet passed through first plate, and slightly indented second. This mantlet is shot-proof, and would in all probability admit of thinner plates without impairing its efficiency.
22	do.	Homogeneous iron	$\frac{1}{4}$	100 6	10 $0\frac{6}{10}$	,,	Bullet-proof at all distances.
23	do.	do	$\frac{3}{16}$	71 12	7 $2\frac{8}{10}$	,,	Not bullet-proof.
24	do.	Homogeneous iron, two plates, $4' \times 2'6''$ and $\frac{1}{4}$ in. apart.	$\frac{1}{8}$	105 12	10 $9\frac{2}{10}$	13 July	Bullets penetrated, and would have passed through first plate, as before, only they were prevented by the closeness of the second; the indentations on the second plate were much greater than when the interval was $1\frac{1}{4}$ ins.
25	Mr Price	Case-hardened, wrought iron, $2' \times 2'6''$.	$\frac{1}{2}$	81 0	16 $3\frac{1}{5}$	13 Aug.	Bullet-proof from 75 yds. down to 10; not one penetrated; slight cracks perceptible in rear of plate.
26	Captain Yonge, R.A......	Homogeneous iron, two plates, $1\frac{1}{4}$ in. apart, with iron bar in centre of plates.	$\frac{1}{12}$ $\frac{2}{12}$	105 6	10 $8\frac{6}{10}$	7 Sept.	Consider them bullet-proof at the shortest range.
27	do.	do	$\frac{1}{12}$ $\frac{2}{10}$	130 2	13 $0\frac{2}{10}$	,,	Bullet-proof at the shortest distance.
28	Colonel Robinson, R.E.	Iron wire rope, $1\frac{1}{2}$ inch in circumference, stretched across a frame front and rear, one side horizontally and the other vertically, pressed close, and screwed with iron staples to the frame, $2'5'' \times 25''$.	$2\frac{1}{2}$ from front to rear; diameter of rope, $\frac{1}{2}$.	102 5	25 8	7 Dec.	Not bullet-proof at 50 yds.; 10 shots penetrated, cutting and displacing the strands.
						1861.	
29	Admiral Sartorius, R.N.	9 homogeneous iron plates, 4 ogee and 5 plain, $2'2'' \times 4\frac{1}{2}''$, riveted on two strips of cow-hide, overlapping.	$\frac{1}{8}$	38 6	5 10	28 Jan.	Not bullet-proof; one shot passed through at 75 yds., and six shots passed through at 50 yds.; several passed through the joints.

ABSTRACT SHEWING THE MEAN INITIAL VELOCITIES OF VARIOUS SERVICE AND EXPERIMENTAL PROJECTILES, DETERMINED BY CAPTAIN ANDREW NOBLE, R.A., UNDER DIRECTION OF THE ORDNANCE SELECT COMMITTEE, BY MEANS OF NAVEZ'S ELECTRO-BALLISTIC APPARATUS.

Nature of ordnance.	No. of rounds.	Charge.	Projectile.			Velocity at 30 yds.	Initial velocity.	Remarks
			Nature.	Weight	Diam.			
		lbs. oz.		lbs. oz.	in.	ft.	ft.	
10-in. gun, 87c	10	12 0	hol. shot	88 5	9·84	1270·4	1292·3	Experiments to ascertain the Initial Velocity of Projectiles fired with Service Charges from Service Guns.
„	5	8 0	Martin's shell	117 0	9·84	930·1	940·6	
68-pr., 95c ...	12	16 0	r. shot	66 4	7·91	1553·3	1579·0	
„	7	16 0	nav. sh.	51 8	7·91	1769·4	1809·9	
„	9	16 0	com. sh.	49 14	7·91	1750·3	1790·7	
„	5	10 0	Martin's shell	60 0	7·84	1287·6	1308·5	
8-in. gun, 65c	5	10 0	com. sh. hol. sh.	46 0	7·85	1455·0	1487·9	
„	5	10 0	com. sh.	49 14	7·85	1434·6	1464·4	
„	5	10 0	Martin's shell	51 8	7·92	1475·8	1506·4	
32-pr., 58c ...	10	10 0	sol. shot	31 6	6·17	1653·7	1690·0	
„	11	8 0	„	31 6	6·17	1584·7	1618·7	
„	11	6 0	„	31 6	6·17	1418·8	1447·5	
24-pr., 50c ...	11	8 0	„	23 8	5·60	1679·5	1720·5	
18-pr., 57c ...	12	6 0	„	17 11	5·09	1646·8	1690·6	
12-pr., 18c ...	10	4 0	„	12 10½	4·52	1718·6	1769·8	
9-*pr. brass, smooth*, 13½c...	4	0 14	*r. shot*	9 5	4·08	at 25 yds 1011·2	1101·6	
„	3	1 8	„	9 5	4·08	1310·9	1444·0	
9-pr., 13c	10	2 8	sol. shot	9 5¾	4·10	at 30 yds 1563·9	1613·7	
6-pr., 6c	10	1 8	„	6 3¾	3·57	1435·3	1484·5	
12-pr. hr., 6½c	10	1 4	com. sh.	8 12	4·55	1124·2	1163·4	
24-pr. hr., 12c	10	2 8	„	16 11½	5·595	1218·0	1252·7	
Wall piece ...	8	drs. 8	shot	0 5¼	0·935	1134·8	1167·6	
Enfield rifle	3	drs. 2·5	ser. ball	grs. 530	0·550	1188·7	1272·8	
6-pr. A., 3½c	15	lbs. oz. 0 12	seg. sh.	lbs. oz. 6 0	2·585	937·5	946·4	
12-pr. A., 8½c	10	1 8	„	11 9	3·084	1180·9	1190·2	
12-pr. A., 8½c	21	1 8	„	10 14½	3·084	1187·5	1197·4	Preliminary experiments with 12-pr Armstrong gun
„	11	1 8	„	11 13	3·083	1181·5	1190·6	Experiments to ascertain the initial velocity of the 12-pr. Armstrong projectile in function of the weight of the shot.
„	5	1 8	„	11 9	3·083	1195·4	1204·8	
„	6	1 8	„	11 5	3·084	1190·8	1200·4	
„	7	1 8	„	11 1	3·083	1205·6	1215·6	
„	11	1 8	„	11 13	3·084	1164·5	1173·4	
„	11	1 8	„	11 5	3·084	1192·9	1202·5	
„	10	1 8	„	10 13	3·084	1209·8	1220·1	
„	10	1 4	„	11 9	3·084	1055·3	1063·1	Experiments to ascertain the initial velocity of the 12-pr. Armstrong projectile in function of the weight of the charge.
„	10	1 6	„	11 9	3·085	1092·4	1100·7	
„	10	1 8	„	11 9	3·084	1180·9	1190·2	
„	10	1 10	„	11 9	3·084	1224·8	1234·6	
„	10	1 12	„	11 9	3·084	1262·0	1272·2	
„	10	0 14	„	11 9	3·084	803·8	809·2	Experiments to ascertain the initial velocity of the 12-pr. Armstrong projectile in function of the weight of the charge. (2nd series).
„	10	1 0	„	11 9	3·084	863·9	870·0	
„	10	1 2	„	11 9	3·084	924·6	931·1	
„	10	1 4	„	11 9	3·084	997·8	1005·1	
„	10	1 6	„	11 9	3·084	1050·2	1058·0	
„	10	1 8	„	11 9	3·084	1106·4	1114·8	
„	10	1 10	„	11 9	3·084	1178·0	1187·3	

ABSTRACT SHEWING MEAN INITIAL VELOCITIES, &c.—*Continued.*

Nature of ordnance.	No. of rounds.	Charge.	Projectile. Nature.	Projectile. Wt.	Projectile. Diam.	Velocity at 30 yds.	Initial velocity.	Remarks.	
		lbs. oz.		lbs. oz.	in.	ft.	ft.		
12-pr. A., $8\frac{1}{2}$ c	5	1 8	Seg. Sh.	11 9	3·080	1184·1	1193·4	Low gauge; bore washed.	Experiments to ascertain the difference between the initial velocities of high and low gauge 12-pr. Armstrong projectiles, and also the effect of lubricating wads.
„ „	6	1 8	„	11 9	3·085	1177·2	1186·5	High gauge, do	
„ „	11	1 8	„	11 9	3·080	1184·1	1193·4	Low gauge; lubricating wads.	
„ „	8	1 8	„	11 9	3·085	1187·8	1197·1	High gauge, do	
„ „	15	1 8	„	11 9	3·072	1154·2	1163·2	G. pattern shell; lubricating wads.	Experiments to ascertain the difference between the initial velocities of old and new pattern 12-pr. A. shells, with or without lubricating wads.
„ „	14	1 8	„	11 9	3·085	1157·1	1166·1	Service shell do	
„ „	13	1 8	„	11 9	3·085	1142·0	1150·8	do } bore washed.	
„ „	10	1 8	„	11 9	3·072	1140·6	1149·4	G. pattern shell } no wads.	
„ „	7	1 2	„	9 0	3·074	1130·0	1141·2	Experiments to ascertain the initial velocity of a 9 lb. shell fired with a charge of 1 lb. 2 oz. from a 12-pr. gun.	
„ „	5	1 8	„	9 0	3·074	1322·2	1336.3	Experiments to ascertain the initial velocity of projectiles fired from a 12-pr. Armstrong gun in function of the weight of the projectile.	
„ „	6	1 8	„	11 9	3·084	1227·4	1237·2		
„ „	6	1 8	„	24 6	3·084	853·9	856·7		
„ „	6	1 8	„	35 14	3·084	720·0	721·5		
„ „	5	1 8	„	47 13	3·084	613·9	614·8		
32-pr. Rifled Shunt gun 59c	4	5 8	Pl. Shells	54·0	6·35	1215·7	1224·5	Experiments to ascertain the initial velocity of a projectile fired from a rifled and of one of the same weight and form fired from a smooth-bored gun.	
„ „	3	5 8	„	54·0	6·35	1122·1	1136·3		
32-pr., 59c, smooth	8	5 8	„	54·0	6·35	1187·4	1201·7		
32-pr. Rifled Shunt Gun...	4	5 8		54·0	6·35	1054·6	1061·7	Cartridge, 12-in. long.	Experiments to ascertain the initial velocities of projectiles fired from a 32-pr. rifled shunt gun, with charges made up in cartridges of various lengths.
„ „	3	5 8		54·0	6·35	1076·8	1084·2	„ 9 „	
„ „	1	5 8		54·0	6·35	1102·2	1109·8	„ 8 „	
„ „	1	5 8		54·0	6·35	1114·5	1122·3	„ $7\frac{1}{2}$ „	
„ „	2	5 8		54·0	6·35	1187·9	1196·4	„ 6 „	
12-pr. A., 6c	8	1 6		11 9	3·074	1103·4	1111·8	Experiments to ascertain the initial velocity of a 12-pr. Armstrong shell fired from a 12-pr. gun of 6c.	
12-pr. A., $8\frac{1}{2}$c	4	1 8		11 9	3·074	1238·3	1248·2 *	Experiments to ascertain the effect of diminishing the lead on the base of the 12-pr. Armstrong projectile.	
„ „	2	1 8		11 9	3·010	1200·2	1209·7 †		
„ „	2	1 8		11 9	3·010	1163·7	1172·8 ‡		
„ „	2	1 8		11 9	3·010	1089·6	1097·9 §		

* Shell fired under normal circumstances.
† Same shell lead reduced to the same diameter as the gun, with the exception of a ring 0·25 inch broad at the base of the original dimensions.
‡ Shell reduced throughout to the diameter of the bore of the gun.
§ Same as last, but a different description of powder employed.

NAVEZ ELECTRO-BALLISTIC APPARATUS.

TABLE SHEWING THE RELATIONS BETWEEN THE ARCS PASSED THROUGH AND THE CORRESPONDING DURATIONS FOR $t = 0''{\cdot}3337$.

By Lieut. W. H. NOBLE, R.A.

Arcs.	Partial Durations.	Total Durations.
°	″	″
30		0·112397
	0·001945	
31		0·114342
	0·001919	
32		0·116261
	0·001895	
33		0·118156
	0·001872	
34		0·120028
	0·001851	
35		0·121879
	0·001830	
36		0·123709
	0·001811	
37		0·125520
	0·001793	
38		0·127313
	0·001775	
39		0·129088
	0·001759	
40		0·130847
	0·001743	
41		0·132590
	0·001728	
42		0·134318
	0·001714	
43		0·136032
	0·001701	
44		0·137733
	0·001688	
45		0·139421
	0·001676	
46		0·141097
	0·001664	
47		0·142761
	0·001653	
48		0·144414
	0·001643	
49		0·146057
	0·001633	
50		0·147690
90		0·209641
	0·001561	
91		0·211202
	0·001566	
92		0·212768
	0·001572	
93		0·214340
	0·001578	
94		0·215918
	0·001585	
95		0·217503
	0·001592	
96		0·219095
	0·001599	
97		0·220694
	0·001607	
98		0·222301
	0·001615	
99		0·223916
	0·001624	
100		0·225540
	0·001633	
101		0·227173
	0·001643	
102		0·228816
	0·001653	
103		0·230469
	0·001664	
104		0·232133
	0·001676	
105		0·233809
	0·001688	
106		0·235497
	0·001701	
107		0·237198
	0·001714	
108		0·238912
	0·001728	
109		0·240640
	0·001743	
110		0·242383
	0·001759	
111		0·244142
	0·001775	
112		0·245917
	0·001793	
113		0·247710
	0·001811	
114		0·249521
	0·001830	
115		0·251351
	0·001851	
116		0·253202
	0·001872	
117		0·255074
	0·001895	
118		0·256969
	0·001919	
119		0·258888
	0·001945	
120		0·260833

ON THE INFLUENCE OF ATMOSPHERIC PRESSURE UPON SOME OF THE PHENOMENA OF COMBUSTION.

By Dr EDWARD FRANKLAND, F.R.S.

Although *the rate of burning* of candles and other similar combustibles, whose flames depend upon the volatilization and ignition of combustible matter in contact with atmospheric air, is not perceptibly affected by the pressure of the supporting medium, yet this is not true of all combustibles. The rate of burning of self-supporting combustibles, like the time-fuzes of shells, depends essentially upon the pressure of the medium in which they are deflagrated. Attention was first called to this fact by Quarter-master Mitchell,* who found that the fuzes of shells burnt longer at elevated stations than when ignited near the level of the sea. The results of the author's experiments with six-inch or thirty-seconds fuzes burnt in artificially rarefied air are embodied in the following table:—

Average pressure of air in inches of mercury.	Average time of deflagration of 6-in. fuze.	Increase of time of burning over preceding observations.	Reduction of pressure corresponding with increase of time.	Increase of time of each diminution of 1-in. pressure.
	seconds.	seconds.	inches.	seconds.
30·40	30·33			
28·25	32·25	1·92	2·15	·893
25·70	34·75	2·50	2·55	·980
22·45	34·75	3·00	3·25	·925
19·65	41·50	3·75	2·80	1·339
15·95	45·50	4·00	3·70	1·081

There are here evident indications of the rate of retardation being somewhat greater at low than at comparatively high pressures; but, neglecting these indications, the above numbers give 1·043 second as the average retardation in a six-inch or thirty-seconds fuze for each inch of mercurial pressure removed. This result agrees closely with that obtained by Quarter-master Mitchell, if we except those fuzes which he burnt at the greatest altitude; and in reference to which some error must obviously have crept in. The following table shews Mr Mitchell's results uniformly with those in the last table. The fuzes which he employed were fifteen-seconds or three-inch ones, and their times of combustion have therefore been

* Proceedings Royal Society, Vol. XI. p. 137.

multiplied by two in order to bring them into comparison with the six-inch fuzes which were used in the author's experiments:—

Pressure of air in inches of mercury.	Average time of combustion of 6-in. fuze.	Increase of time of combustion over last observation.	Reduction of pressure corresponding to increase of time.	Increase of time for each diminution of 1-in. pressure.
	seconds.	seconds.	inches.	seconds.
29·61	28·50			
26·75	31·56	3·06	2·86	1·070
23·95	34·20	2·64	2·80	·943
22.98	36·25	2·05	·97	2·113

Here, omitting the last determination as abnormal, we have the average retardation, in the combustion of a six-inch fuze, for each diminution of one-inch mercurial pressure, equal to 1·007 second, which coincides almost exactly with the number (1·043) deduced from the author's experiments.

The results of both series of observations may therefore be embodied in the following law:—*The increments in time are proportional to the decrements in pressure.* For all practical purposes the following rule may be adopted:—*Each diminution of one inch of barometrical pressure causes a retardation of one second in a thirty-seconds fuze*; or, *each diminution of atmospheric pressure to the extent of one mercurial inch increases the time of burning by one-thirtieth.*

This retardation in the burning of time-fuzes by the reduction of atmospheric pressure will probably merit the attention of artillery officers. Up to the present moment these fuzes have been carefully prepared so as to burn, at Woolwich, a certain number of seconds; but such time of combustion at the sea-level is no longer maintained when the fuzes are used in more elevated localities. Even the ordinary fluctuations of the barometer in our latitude must render the time of the combustion of these fuzes liable to a variation of about ten per cent. Thus a fuze driven to burn thirty seconds when the barometer stands at 31 inches, would burn thirty-three seconds if the barometer fell to 28 inches. Even the height to which a shell attains in its flight must exert an appreciable influence upon the burning of its time-fuze; to a still greater extent, however, must the time of combustion be affected by the position of the fuze during the flight of the shell. If it precede the shell, the time of burning must obviously be considerably shorter than if it follow in the comparatively vacuous space behind the shell.

The apparently opposite conclusions to which we are led as regards the influence of atmospheric pressure upon the *rate* of combustion, by the experiments upon candles on the one hand and upon time-fuzes on the other, are by no means irreconcileable; in fact, an examination into the conditions of combustion in the two cases scarcely leaves room for the expectation of any other result. In the combustion of a candle, the author proves that, at all pressures, there is a sufficient supply of melted combustible matter kept up at the base of the exposed portion of the wick: the capillarity of the

latter is not affected by pressure; and as the temperature of the flame is also proved to remain practically constant, effecting the evaporation of the same amount of combustible matter under all pressures, it follows that the rate of consumption of a candle must be nearly or quite independent of the pressure of the surrounding medium. In the deflagration of time-fuzes, the conditions are obviously very different. Here the combustible matter never comes into contact with atmospheric oxygen until it has been ejected from the fuze-case. Unlike the candle, the composition contains within itself the oxygen necessary for combustion, and a certain degree of heat only is necessary to bring about chemical combination. If this heat were applied simultaneously to every part of the fuze composition, the whole would burn almost instantaneously. Under ordinary circumstances, however, the fuze burns only at a disk perpendicular to its axis; and the time occupied in its deflagration necessarily depends upon the rapidity with which each successive layer of composition is heated to the temperature at which chemical combination takes place. This heat, necessary to deflagration, is evidently derived from the products of the combustion of the immediately preceding layer of composition; and the amount of heat thus communicated to the next unburnt layer must depend, in great measure, upon the number of particles of these heated products which come into contact with that layer. Now, as a large proportion of these products are gaseous, it follows that, if the pressure of the surrounding medium be reduced, the number of ignited gaseous particles in contact at any one moment with the still-unignited disk of composition will also be diminished. Hence the slower rate of deflagration in rarefied air.

ON THE DETERMINATION OF RANGE TABLES FOR RIFLED ORDNANCE.

By COLONEL LEFROY, R.A., F.R.S.

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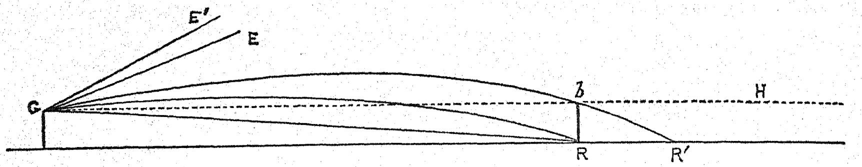
1. The Range Tables in universal use in our service profess to give the true mean horizontal range of the projectile; that is to say, the distance from the gun at which the shot touches the horizontal plane on which the carriage is placed. Thus we see for point blank range, or 0° of elevation, a range assigned of 300 yds., or some such quantity, leaving it to be inferred that 0° elevation is proper for all distances up to 300 yds., unless we adopt the alternative that something less than 0° of elevation, *i.e.* a depression, is to be given to strike an object within that distance; that this cannot really be the case is self-evident. The anomaly arises from inaccurate definition of the range of a shot: a gun is not fired at 300 yds., or indeed, generally speaking, at any other distance, to strike the ground, but to strike an object above the ground; and the elevation to be given must be such that the trajectory shall pass through the point aimed at, consequently giving a greater horizontal range than the distance to the foot of the object,—we acknowledge this in musketry fire, and it is the principle which regulates the sighting of all rifles. The irregularities of fire make the distinction practically of no importance at considerable distances; but it is far otherwise at short ranges, where the precision of rifled guns makes it possible to strike a small mark, and it becomes necessary to adopt the following precise definition of range:—

(1) *By the range due to a given elevation, is meant the distance from the muzzle of the gun to the second intersection of the trajectory with the line of sight (the first intersection being close before the muzzle).*

Note.—The following is extracted from the *Règlement sur le service du canon de 4 rayé de campagne systeme la Hitte*, 1860. It is to be regretted that we have no term equivalent to *but en blanc*, as distinct from *portée*, and are obliged to take the term range; but it must be well observed that there is nothing inconsistent between this definition of range and the common sense of it, and nothing whatever to prevent the word in ordinary language being used to signify the distance to the first graze of the shot on horizontal ground. But then it should be understood that the *tabular range* is *the distance to the object or target;* and if the shot misses that object and goes further, or strikes, and passes through it to the ground, the range on the ground corresponds in the Table to a slightly larger angle,—to the angle in fact which would be given if the object intended to be struck were at the distance of the point actually struck. The Americans call the *portée de but en blanc* the *point blank range*, we call it the line of metal range. When a gun is laid directly on an object by line of metal, it is said by them to be laid *point blank*.* This definition is of course inconsistent with the use of disparts; with the Armstrong guns, which

* Gibbon's "Artillerists Manual," 1860, p. 226.

(2) For example, let G be the muzzle of a gun 4 ft. above the plane, and b a small object also 4 ft. above the plane at 1000 yds. distance.



Then the elevation E for 1000 yds. by the Tables will cause the shot to strike the ground at R, 4 ft. vertically under b, and if we want it to strike b we must give it some elevation E' due to a greater range R'; but if the tabular elevation were the angle EGR instead of the angle EGH, then because there is no sensible difference between EGR and $E'Gb$, in other words, because the second intersection of the trajectory with the line of sight is at the same distance from the muzzle whether this line be slightly inclined like GR or level like Gb, then it would be sufficient in each case to direct the line of sight on the object, and to give the tabular elevation above it.

(3) There are three ways of conducting the experimental practice at the School of Gunnery upon which our Tables are based :—

First.—The gun is on a travelling carriage on the sands, and the elevations given by tangent scale above a mark of the same height as its own axis, viz. 3 ft. 6 in. to 4 ft. 6 in.

Second.—The gun is on a naval carriage with the axis 8 ft. above the sands, and the elevations are in this case also generally given by tangent, above a mark of the same height as the axis.

Third.—The gun is on a garrison or other carriage with the axis about 17 ft. above the plane, and the elevations are either given by spirit-level, or given by tangent above a mark of a known height at a known distance.

In either case the *elevation recorded is that given by the tangent scale or the quadrant as the case may be, and the range recorded is the distance of the first graze on the sands.*

The following Table of 40-pr. practice under all these different conditions will shew how variable the results are when erroneously referred to these nominal elevations instead of the true elevation.

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have a line of metal elevation of 6′, it might be used, and it would then be exactly consistent with the definition given above,

"Le premier point de rencontre de la trajectoire avec la ligne de mire étant très rapproché de la pièce, on n'a pas à s'occuper du tir sur un but situé entre ce point et la bouche.

"Le second point de rencontre de la trajectoire avec la ligne de mire se nomme *but en blanc*, et sa distance à la pièce *portée de but en blanc.*

"Quelle que soit l'inclinaison de la ligne de mire naturelle en dessus ou en dessous de l'horizon, dans les conditions ordinaires du tir, la *portée de but en blanc* reste sensiblement la même. Cependant, on appelle plus spécialement *portee de but en blanc* la portée obtenue quand la ligne de mire est horizontale.

"Cette portée est de 500 m. pour le canon de 4, rayé, de campagne.

"Ainsi, pour atteindre un but placé à 500m., il faut pointer directement sur ce but par le fond des crans de mire de la culasse et du bourlet."—*Reglement, &c.*, p. 91.

TABLE I.

MEAN RANGES OBTAINED IN 40-pr. PRACTICE UNDER THE FOLLOWING CONDITIONS.

(*a*) Gun on a travelling carriage; axis $4\frac{1}{2}$ ft. above the plane; elevation given by tangent scale above a mark $4\frac{1}{2}$ ft. above the plane, which is nearly a dead level.

(*b*) Gun on a naval carriage; axis 8 ft. above the plane; elevation given by tangent scale above a mark 8 ft. above the plane.

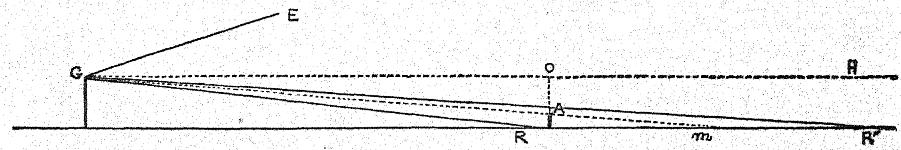
(*c*) Gun on a garrison sliding carriage; axis $17\frac{1}{2}$ ft. above the plane; elevation given by spirit-level.

Observed mean Ranges.

Nominal elevation.	(*a*) $4\frac{1}{2}$ ft.	(*b*) 8 ft.	(*c*) $17\frac{1}{2}$ ft.
0°	312 *y*	376 *y*	492 *y*
1°	682	723	783
2°	1061	1077	1151
3°	1429	1448	1491
4°	1779	1806	1873
5°	2116	2129	2274
6°	—	2563	—
7°	2727	2925	2955
8°	—	3186	—
9°	3303	3562	3454
10°	3377	3751	—

The above are the means of solid shot, common shells and segment shells, because we recognize no difference in the range of those projectiles, nor is there in fact, practically, any sensible difference. It is evident that unless we are prepared to promulgate different Tables for every sort of service, these results must be harmonized into some general Table which shall be true for the gun, however it is situated relatively to the object to be struck. This is fortunately very easy.

4. Let h = height of the axis of the gun above the plane,
a = distance of the mark above which the elevations are given,
b = the height of that mark above the plane,
R = the horizontal range recorded,
θ = elevation by tangent sight above the mark b,
θ_1 = the true angle to which the range R is to be referred.



(1) Then let us first suppose the case of the gun laid at the given object b for direction; but the elevation given by spirit-level. In this case the height of the object b is immaterial, the angle recorded namely EGH of

the figure (p. 19), simply requires a +correction HGR, when it will be converted into the angle EGR,

$$HGR = \tan^{-1}\frac{h}{R} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad \text{I.}$$

6′ must be subtracted to reduce it to tangent elevation, because the zero of the tangent scale in all Armstrong's guns gives an elevation of 6′ as referred to the axis.

(2) The effect is the same if the gun is laid by tangent sight at an object the same height above the plane as its own axis; remembering however that when the tangent sight is at zero the axis of the gun has an elevation of 6′, as above stated, and therefore that the line of sight GH is not the same as when the gun is laid by spirit-level on the true horizon.

(3) Next let us suppose the gun laid at the mark b, not the same height as itself, and the elevation given by tangent above b. This is the common case when the guns are fired from the permanent platforms at Shoeburyness, and the elevation is given above a mark 7 or 8 ft. high at 1000 yds. or some other known distance.

The angle θ recorded is EGA of the figure, p. 19: the true angle θ_1 to which the ranges must be ascribed is EGR' or EGR, according as the range is less or greater than the distance m of GA produced.

Knowing the height of the axis of the gun and of the mark A, we know the angle of depression of A, namely the angle whose natural tangent

$$= \frac{h-b}{a} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad \text{I.}$$

In like manner,

$$HGR = GRL = \frac{h}{R} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad \text{II.}$$

The correction to the elevation then is

$$e = \tan^{-1}\frac{h-b}{a} - \tan^{-1}\frac{h}{R} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad \text{III.}$$

and is additive when the second angle is greater than the first; this is the case when R falls within the distance a.

In words. Find the angle of depression OGA of the mark above which tangent elevations are given.

Find the angle subtended by the height of the gun at each mean range. Add the difference of these two angles to the given elevation as long as the second is the greater, which it will be for all ranges less than m: subtract the difference from the given elevation, when the second angle is the less, which it will be for ranges beyond m.

When Gm coincides with GH, i.e. when the gun is laid by spirit-level or at a mark of the same height as its own axis, the correction is simply the angle subtended by the height of the gun at each distance R, and is always additive.

5. Let us now examine Table I. after applying these corrections to the angles.

TABLE II.

RANGES OF 40-pr. GUN CORRECTED FOR THE DIFFERENT HEIGHTS OF THE AXIS, AND REDUCED TO THE TRUE ANGLE AS DEFINED, *par* 1.

Elevation by *T*.		Yards.	Elevation by *T*.		Yards.	Elevation by *T*.		Yards.
°	′		°	′		°	′	
0	16·5	312	4	2·9	1779	......		—
0	24·4	376	4	5·1	1806	......		—
0	34·8	492	4	4·7*	1873	8	2·9	3186
1	7·6	682	5	2·5	2116	......		—
1	12·7	723	5	4·3	2729	9	1·6	3303
1	19·1	783	5	2·8	2274	9	2·6	3562
2	4·9	1061	......		—	8	59·8	3454
2	8·6	1077	6	3·6	2503	10	1·5	3577
2	11·4	1151	......		—	10	2·5	3751
3	3·6	1429	7	1·9	2727	......		—
3	6·5	1448	7	3·2	2925			
3	7·4	1491	7	0·8	2955			

6. If the irregularities do not entirely disappear from the foregoing Table, it will at least be admitted that they are greatly reduced in amount; for the rest we must fall back on the variable circumstances of wind and weather attending each series. Speaking generally, the practice on the travelling carriage up to 5° was favoured by a moderate wind down the line of fire; above 5° the wind crossed the line of fire, and had little or no influence on the range. The practice on the naval carriage was made with wind crossing the line of fire, and the ranges will be little affected by it. The practice on the garrison carriage was made with a prevalence of high wind down the line of fire, and the ranges are beyond doubt considerably augmented by it.

7. The practical conclusion from the whole is,

First.—Our fundamental Range Tables should be so made out as to have no reference to the height of the axis of the gun, or the relative position of the gun and the object intended to be struck, within common or moderate limits.

Secondly.—All that is requisite is, that however the recorded angles of elevation be obtained, the corrections shewn above be applied to make true angles of them, before they are combined graphically or otherwise to deduce Tables of mean ranges for even degrees of elevation, or of mean elevation for given distances.

Thirdly.—It is to be understood that the tabular elevations mean the elevations proper to strike the point above which each elevation is given, and the gun is to be laid at that point, *e.g.* the centre of a target and not the bottom or the top, or a man's height, or any other arbitrary object.

Fourthly.—The inaccurate practice of laying high or low to correct a bad shot should be avoided: the proper and only accurate course is to lay again at the same point but give more or less elevation, the gunner then

* The reason the third angle here begins to be less than the second is, that the constant correction of − 6′ to reduce quadrant elevations to tangent elevations exceeds the + correction.

knows what he is about, and what elevation he is really using; for example, the difference between the centre and the bottom or the top of a 9 ft. target at 1000 yds. is $\mp$ 5′, if this correction is required it should be fairly given on the tangent scale. Equally at variance with correct principle is, the common practice of laying at the top of the target when the intention is that the shot shall strike about the centre. It is simply recording an elevation less than it would be if it were given above the point struck or meant to be struck, but does not alter the facts of the case, or the relation of the axis of the gun to the proper line of sight. It makes a difference of 4′ or 5′ at 1000 yds., the target being 9 ft. square. The object is sometimes explained to be that by so doing the shot strikes short, and the gunner can correct his aim next time; he could do this equally well, and preserve consistency, by aiming at the point he intends to strike, but giving 4′ or 5′ less elevation than is due to the estimated distance. For example,—March 10, 1862, A squad at exercise fired 22 rounds with a 12-pr. at a 9 ft. target, distant 1000 yds., and all the shots struck. Table III. assigns 1°, 50′ as the proper elevation to strike the centre of the target at 1000 yds., the gun being laid at that centre: the actual elevations given were 1°, 47′ to 1°, 53′ the gun being laid near the top, or 1°, 51′ to 1°, 57 as referable to the centre. It is difficult to see what difference in practice it would have made to the gunner if he had been taught to lay at the centre and give 1°, 50′ which would have struck low, and have been corrected next time; or if 1°, 50′ proves eventually rather too small a mean elevation, if he had given 1°, 53′ or whatever else may be the ultimate tabular quantity. In principle however it makes a material difference whether he is taught to expect to strike the point he lays on, or to strike another point. Range tables can be as easily accommodated to one system as the other—but the one is accurate, consonant with the instructions of theory, with musketry practice, and with the practice of other artilleries; the other is arbitrary and, in principle, inaccurate. It is scarcely necessary to remark that mean ranges, as the term implies, are not the actual ranges under all conditions; the judgment of the officer must under any circumstances direct him how closely to follow the table,—and when to deviate from it.

8. The following Tables are deduced from actual practice in the manner here recommended, subject to future correction from better data :—

TABLE III.

Nature.	6-pr. 3½c.		9-pr. 6c.		12-pr. 8½c.		20-pr. 16½c.	
Charge.	12 oz.		1 lb. 2 oz.		1 lb. 8 oz.		2 lbs. 8 oz.	
	Elev.	*T.*	Elev.	*T.*	Elev.	*T.*	Elev.	*T.*
yds.	° ′	sec.	° ′	sec.	° ′	sec.	° ′	sec.
200	0 14	0·58			0 16	0·60	0 25	0·40
300	0 24	0·86			0 25	0·85	0 39	0·90
400	0 36	1·22			0 35	1·12	0 53	1·25
500	0 50	1·56			0 46	1·45	1 8	1·57
600	1 6	1·92			0 58	1·82	1 23	1·90
700	1 23	2·30			1 10	2·14	1 38	2·25
800	1 41	2·65			1 22	2·46	1 53	2·58
900	2 0	3·00			1 35	2·75	2 9	2·90
1000	2 20	3·36			1 50	3·06	2 26	3·26
1100	2 42	3·73			2 6	3·40	2 44	3·60
1200	3 4	4·10			2 23	3·75	3 3	3·96

TABLE III.—*Continued.*

Nature.	6-pr. 3½c.		9-pr. 6c.		12-pr. 8½c.		20-pr. 16½c.	
Charge.	12 oz.		1 lb. 2 oz.		1 lb. 8 oz.		2 lb. 8 oz.	
	Elev.	*T.*	Elev.	*T.*	Elev.	*T.*	Elev.	*T.*
yds.	° ′	sec.	° ′	sec.	° ′	sec.	° ′	sec.
1300	3 26	4·47			2 39	4·10	3 22	4·30
1400	3 48	4·83			2 58	4·43	3 41	4·63
1500	4 10	5·20			3 17	4·78	4 0	5·00
1600	4 33	5·60			3 35	5·15	4 19	5·35
1700	4 56	6·00			3 53	5·50	4 38	5·68
1800	5 20	6·40			4 11	5·82	4 57	6·02
1900	5 45	6·78			4 30	6·18	5 16	6·38
2000	6 10	7·20			4 49	6·48	5 36	6·72
2100	6 38	7·60			5 10	6·88	5 57	7·10
2200	7 6	8·02			5 32	7·27	6 18	7·50
2300	7 35	8·46			5 53	7·65	6 39	7·84
2400	8 2	8·90			6 15	8·03	7 0	8·22
2500	8 30	9·32			6 36	8·42	7 22	8·58
2600	9 0	9·80			7 0	8·81	7 43	8·92
2700	9 30	10·30			7 23	9·22	8 4	9·30
2800	10 0	10·78			7 46	9·64	8 25	9·68
2900	10 33	11·28			8 7	10·04	8 46	10·05
3000	11 3	11·80			8 30	10·45	9 7	10·41
3100	......	......			8 56	10·87	9 28	10·80
3200	......	......			9 22	11·28	9 49	11·20
3300	......	......			9 48	11·70	10 10	11·55
3400	......	......			10 14	12·15	10 32	11·90

TABLE IV.

Nature.	40-pr.		110-pr.			
Charge.	5 lbs.		12 lbs. shells.		14 lbs. shot.	
	Elev.	*T.*	Elev.	*T.*	Elev.	*T.*
yds.	° ′	sec.	° ′	sec.	° ′	sec.
100						
200	0 14		0 20	0·5	0 20	
300	0 21	1·0	0 32	1·00	0 30	
400	0 30	1·27	0 46	1·36	0 40	
500	0 42	1·52	0 58	1·66	0 52	
600	0 55	1·79	1 11	1·96	1 5	
700	1 10	2·08	1 26	2·31	1 17	
800	1 25	2·38	1 40	2·66	1 30	
900	1 40	2·69	1 55	3·00	1 44	
1000	1 56	2·90	2 11	3·34	1 58	
1100	2 12	3·31	2 27	3·68	2 12	
1200	2 27	3·62	2 44	4·00	2 26	
1300	2 43	3·93	3 2	4·36	2 41	
1400	2 59	4·24	3 20	4·70	2 57	
1500	3 15	4·55	3 38	5·10	3 13	
1600	3 31	4·86	3 56	5·43	3 30	
1700	3 47	5·18	4 14	5·80	3 47	
1800	4 3	5·50	4 32	6·20	4 4	
1900	4 19	5·83	4 51	6·51	4 21	
2000	4 35	6·16	5 10	6·85	4 39	
2100	4 41	6·49	5 29	7·20	4 57	
2200	5 7	6·82	5 48	7·57	5 15	
2300	5 24	7·14	6 7	7·90	5 34	
2400	5 41	7·47	6 26	8·28	5 53	
2500	5 59	7·79	6 45	8·67	6 12	
2600	6 17	8·12	7 5	9·00	6 32	
2700	6 36	8·45	7 25	9·38	6 52	
2800	6 56	8·78	7 44	9·83	7 12	

TABLE IV.—*Continued.*

Nature.	40-pr.		110-pr.			
Charge.	5 lbs.		12 lbs.		14 lbs.	
	Elev.	*T.*	Elev.	*T.*	Elev.	*T.*
yds.	° ′	sec.	° ′	sec.	° ′	sec.
2900	7 16	9·12	8 4	10·20	7 32	
3000	7 36	9·46	8 23	10·45	7 52	
3100	7 57	9·81	8 43	10·80	8 12	
3200	8 8	10·20	9 3	11·17	8 32	
3300	8 29	10·63	9 23	11·50	8 51	
3400	9 1	11·08	9 43	11·85	9 10	
3500	9 23	11·54	10 3	12·20	9 29	
3600	9 45	11·98	10 23	12·54	9 48	
3700	10 8	12·46	10 43	12·88	10 7	
3800	10 32	12·98	11 3	13·22	10 26	
3900	10 58	13·50	11 24	13·57	10 46	
4000	11 26	14·00	11 45	13·93	11 7	

9. To make this subject complete, I subjoin a corresponding Table for the guns and charges peculiar at present to the naval service, as far as completed.

TABLE V.

Nature.	12-pr.		20-pr.	
Charge.	1 lb. 8 oz.		2 lb. 8 oz.	
	Elev.	*T.*	Elev.	*T.*
yds.	° ′	sec.	° ′	sec.
100	The difference of range between the land service or 7 ft. 12-pr., and the sea service gun of 6 ft. is too small to require separate tables, a + correction of from 2′ to 3′ per degree of elevation is sufficient.		—	—
200			0 20	—
300			0 33	1·06
400			0 47	1·40
500			1 4	1·75
600			1 22	2·10
700			1 41	2·44
800			2 21	2·79
900			2 21	3·16
1000			2 42	3·52
1100			3 4	3·88
1200			3 26	4·29
1300			3 48	4·60
1400			4 10	4·98
1500			4 32	5·36
1600			4 54	5·74
1700			5 16	6·15
1800			5 38	6·56
1900			6 1	6·98
2000			6 24	7·38
2100			6 48	7·80
2200			7 12	8·20
2300			7 36	8·62
2400			8 1	9·06
2500			8 28	9·50
2600			8 56	9·93
2700			9 25	10·37
2800			9 53	10·80
2900			10 22	11·26
3000			10 51	11·75
3100				
3200				
3300				

10. The ranges recorded at Shoeburyness and which have formed the basis of the foregoing Tables, are subjected to two operations.

(*a*) Having found the arithmetical mean of all the ranges for a given elevation, the deviation of each individual range from this mean is taken out, and the average of these differences, without regard to sign, is called the *mean difference of range*.

(*b*) Each shot is referred to a datum line for deflection; the mean of all the deviations from this line, taken *with* regard to sign, is the true mean direction of all the shots, as referred to the datum. This quantity again, being subtracted from each observed deflection, the remainder is the deflection of the shot as referred to the mean direction of the whole, and the average of these remainders, taken without regard to sign, is the *true mean deflection* of the series after eliminating wind, *derivation* as our neighbours call it, or drift, and any other constant error, such as want of verticality in the tangent sight. It correspondes in fact to the *figure of mirit* in rifle practice.

I subjoin an extract of these quantities for various series of practice, taking the results at 2°, 5°, and 10° as a criterion of the whole. It so happens that up to the present time the 40-pr. has been fired less frequently than the other guns under circumstances giving a mean of 10 or more exactly comparable shots at 10°. Less than 10 rounds will give a very reliable mean range, but not so reliable a difference of range, or mean deflection.

Table VI.

MEAN DIFFERENCES OF RANGE AND MEAN DEFLECTIONS OF ARMSTRONG GUNS OBSERVED ON CERTAIN OCCASIONS OF EXPERIMENTAL PRACTICE, WITH THE MEAN RANGE TO WHICH THEY BELONG.

Date.	2°				5°				10°			
	No. of rounds.	Mean range.	Mean differ. of range.	Mean Deflection.	No. of rounds.	Mean range.	Mean differ. of range.	Mean Deflection.	No. of rounds.	Mean range.	Mean differ. of range.	Mean Deflection.
		yds.	yds.	yds.		yds.	yds.	yds.		yds.	yds.	yds.
9-pr. Charge, 1 lb. 2 oz.												
4/ 1/62	20	920	19·7	0·77	20	1821	20·2	1·57	20	2980	26·0	3·371
12-pr. Charge, 1 lb. 8 oz.												
25/ 2/61	20	988	12·9	0·37	20	2006	11·4	0·60	20	3249	22·5	4·46
20/10/61	—	—	—	—	10	2019	25·8	1·00	10	3304	31·9	1·80
3/12/61	10	1089	10·3	0·50	10	2081	11·7	1·10	10	3399	24·2	0·80
"	10	1101	12·4	0·60	10	2111	12·3	1·40	10	3418	18·1	0·90
6/ 1/62	20	1102	18·1	0·55	20	2116	12·8	1·20	20	3480	21·3	2·40
L. S. 20-pr. Charge, 2 lbs. 8 oz.												
6/12/61	10	810	9·0	0·50	10	1595	33·5	1·50	9	2368	24·8	1·10
6/12/61	10	810	5·7	0·30	10	1600	45·3	0·60	—	—	—	—

TABLE VI.—*Continued.*

Date.	2° No. of rounds.	2° Mean range.	2° Mean differ. of range.	2° Mean deflection.	5° No. of rounds.	5° Mean range.	5° Mean differ. of range.	5° Mean deflection.	10° No. of rounds.	10° Mean range.	10° Mean differ. of range.	10° Mean deflection.
		yds.	yds.	yds.		yds.	yds.	yds.		yds.	yds.	yds.
40-pr. Charge 5 lbs.												
4/ 3/61	10	1059	19·5	0·68	...	...	...					
”	10	1096	12·8	0·49	...	...	...					
9/ 9/61	9	1117	21·9	1·30	10	1966	16·8	1·00				
”	10	1047	11·8	0·30	10	2032	34·7	2·48				
”	...	...	...	...	20	2106	29·4	2·33				
30/10/61	...	...	...	...	16	2100	36·1	1·80				
”	...	...	...	...	17	2102	18·3	1·70				
22/ 1/62	20	1128	16·6	0·71	20	2155	23·8	1·83	20	3672	19·5	2·33
24/ 1/62	19	1235	17·1	0·70	...	...	...	...	20	3847	30·5	3·78
110-pr. Charge 12lbs.												
15/ 1/61					20	1839	15·7	51·46				
14/ 2/61	20	1010	20·25	0·53	...	...	...					
16/ 4/61	...	...	...	...	...	...	...	...	20	3493	45·46	3·40
24/ 5/61	...	...	...	...	...	...	...	...	15	3594	42·33	4·50
17/ 8/61	10	1197	28·60	1·45	10	2309	29·5	4·45				
									15	3791	61.9	11·45

11. It results from the foregoing Table that up to 5° of elevation, the average deviation of any shot from the mean range which would be given by a continuance of practice, under the same circumstances, varies between 0·007 and 0·029 of the whole quantity, or from less than one-hundredth to nearly three-hundredths of the actual ranges (the average is about ·014 or one-hundredth and a half). Irregularity in the strength of the powder, difference in the direction and force of the wind, and many other causes contribute to make the range different on different occasions, but each shot is true within these limits, to the circumstances of the moment; and the second may be corrected by the first with a confidence unknown to smooth-bore practice.

12. A line of troops subtends an angle of between 3′ and 4′ at 2000 yds. and the hull of a vessel 12 ft. out of the water, an angle of between 7′ and 8′. The height of the first allows a latitude of 20 or 30 yds. of range, and of the second a latitude of 60 or 70 yds. in the estimation of distance, and to this approximation should it if possible be ascertained. At least three centuries ago, Nicholas Tartaglia expressed the importance of this question in language not the less true for its quaintness, and as the subject cannot be too frequently brought before the artilleryman, I quote his words below.

Au très-illustre et très-invincible Seigneur Francois Marie de Feltre de la Rovère, excellentissime duc d'Urbin et de Sora, &c.

"Ensuite, magnifique seigneur, j'ai considéré que toutes ces diverses connaissances seraient de "fort peu de secours à un artilleur, s'il ne connaissait pas la distance du lieu où il doit faire

"arriver ses coups. Supposons, par exemple, qu'il eût à tirer sur un lieu apparent, mais "dont l'éloignement lui fût inconnu, à quoi, ô duc magnanime, lui servirait en cette "occasion de savoir que sa pièce sous tel angle porterait à 1,356 pas, sous tel autre à 1,458, et "sous tel autre encore à 1,574 pas, et ainsi de suite, de degré en degré. A coup sûr cela ne lui "servirait à rien, puisque, ignorant la distance, il serait dans l'impossibilité de choisir "l'élévation sous laquelle il devrait tirer sa pièce pour atteindre le but proposé. Il suit de "là que deux choses principales sont nécessaires à un artilleur qui tient à tirer d'une manière "rationnelle, et non au hasard, deux choses tellement liées l'une à l'autre, que la connaissance "de la première devient tout à fait inutile sans celle de la seconde (je parle ici de tirs à de "longues distances). La première de ces choses consiste à savoir reconnaître et déterminer "approximativement à la vue la distance du lieu qu'il s'agit de battre; la seconde est de "connaître la grandeur des portées de la pièce sous les différents angles d'élévation."

La Balistique de Nicholas Tartaglia, first published in 1537, translated from the Italian by Professor Rieffel. Paris, 1845.

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13 We have referred in *par.* 1 to the necessity for more precise definitions of terms than are usually given in English books of Gunnery. Distinctions of importance are often lost sight of for want of them, or the same terms used loosely to express different things. This applies particularly to the terms elevation and range. I have endeavoured in the following to express as succinctly as possible what appear to be the principal definitions in rifled gunnery, and submit them with all due respect to the judgment of officers engaged in instruction. The French equivalents are in some cases added.

Definitions in Gunnery.

1. Plane of Fire.—The vertical plane passing through the axis of the gun.

2. Angle of Elevation.—*Angle de mire.* The angle between the axis of the gun and the visual line from the sight on the tangent scale to the object. It has no reference to the horizon or to any natural level.

3. Angle of Inclination.—*Angle de tir.* The angle which the axis of the gun forms with the true horizon, or the angle shewn by a correct spirit-level. This is consequently the angle recorded when guns are laid by quadrant.

4. Angle of Departure.—*Angle de projection.* The actual angle which the shot's path on leaving the muzzle makes with the true horizon; this when there is windage may differ sensibly from the *angle of inclination*, and appears also to do so in the lighter rifled guns where the shot are observed to rise, from the muzzle being slightly thrown up.

5. Range.—The distance from the muzzle of the gun to the second intersection of the trajectory with the line of sight (the first intersection is made near the muzzle, where the shot in its ascent crosses the line of sight). The range is *not* accurately the distance to the point at which the shot impinges on the plane, unless that is also the point aimed at, but the difference is practically of importance only at short distances.

There is no such thing as point blank range, and this term which has no equivalent in French, should if possible be disused, or its conventional meaning be very carefully guarded. What is usually called point blank range, viz. the distance at which a shot impinges on a level plane when fired parallel with it, is really the range due to *an angle of elevation* equal to the angle subtended by the height of the gun from the point struck. The *portée de but en blanc* of the French is what we term the *line of metal range*, referred however not to the plane, but to the second intersection of the trajectory with the line of sight.

6. Point Blank.—A gun is only laid point blank when the axis prolonged passes through the object aimed at. The term had its origin in the erroneous notion of the gunners before Robins that every shot travelled a certain, and indeed a considerable distance, in a right line before it was acted upon by gravity, and to them point blank range expressed a definite although imaginary distance. The use of the term at present is productive of much confusion.

"Shooting Point Blank is when your mark you Shott at may be reacht in a Direct line without Curvity. A peice may be Elevated and yet shoot blank. For two peices on one and the same Battery being both within Blank the one may be layd level the other may Elevated so as to batter the same Fortificacation only some part that is higher. Therefore a peice may be Elevated and yet shoot Point Blank. But it must be within the right line of the peices reach."—Cocker's *Gunnery* (MS. War Office, 1710).

7. Terminal Angle.—*Angle de chute*. The angle which a tangent to the trajectory forms with the horizontal plane at the point of descent.

8. Angle of Incidence.—*Angle d'incidence*. The angle which the tangent to the trajectory makes with the actual surface at the point of descent.

9. Angle of Descent.—*Angle d'arrivée*. The angle which the tangent to the trajectory makes with the horizon at the height of the crest of the parapet, or other object to be cleared. It is rather less than the terminal angle.

10. Height of the Object.—Distance of the point intended to be struck above or below the horizontal plane passing through the mouth of the piece. Thus, if the height of the muzzle of the gun above the zero plane is 17 ft., and the point intended to be struck is the centre of a 9 ft. target on the plane, the height of the object will be *minus* $12\frac{1}{2}$ ft.

11. Elevation of the Object.—Angle which a straight line drawn from the object to the centre of the mouth of the piece makes with the true horizon.

12. Line of Metal.—*Ligne de mire naturelle*. Right line connecting the front and back sight when the latter is at its lowest point, *i.e.* connecting the notch on the tangent sight with the notch on the swell of the muzzle or dispart sight, in smooth-bored guns, connecting the tangent and trunnion sight, or the ratchet and dispart sight in Armstrong guns.

13. Line of Sight.—*Ligne de mire artificielle*.—Right line from the extremity of the tangent scale, at whatever elevation, to the front sight whatever it is. When this line is directed on the object it becomes the line from which angle of elevation of the axis (1) is measured.

REMARKS ON IRON DEFENCES.

By CAPTAIN H. C. S. DYER, R.A.

The first experiment recorded was carried on at Woolwich in 1827, at the instance of General Ford, R.E., who proposed to protect masonry with wrought-iron bars.* To test the value of this proposal, a block of Dundee stone 6 × 5 × 2 feet was covered with 1¼-inch wrought-iron bars in horizontal courses, these were covered with another layer of 1½-inch bars placed vertically. The target was fired at with 24-pr. solid cast-iron shot, at a range of 634 yds.: after 20 rounds had struck, 19 of the front bars and 5 of the horizontal course were broken, 4 bars were detached. The result of this experiment was considered so unsatisfactory that all idea of using iron as a means of defence was for the time abandoned; it was again revived about the year 1850, by Lord Ross and others, but apparently the time had not yet arrived for these sweeping changes in old established notions, and it was reserved for the Emperor Napoleon III. to bring the question to a practical issue.

The superiority of the French floating battery engaged at Kinburn in 1855, over the wooden ships engaged at the same time was so indisputably proved, that the Admiralty determined on providing themselves with some vessels of this class; two of them reached the Baltic a short time before peace was declared, and were not required. As these vessels owing to the great weight of their armour, and being provided with engines of such small power, could only be made available for coast defences, it was determined to construct others which should be invulnerable, without sacrificing the important element of speed. Before proceeding in the construction of these ships, it was considered advisable to determine by experiment the best mode of disposing the armour for defence. For this purpose a committee was formed in July 1859, and carried on experiments on various descriptions of iron until April 1860, when the question was handed over to the Ordnance

* "A wall 5 ft. high and 7 ft. thick, built of the best Aberdeen granite blocks, cased with two layers of iron bars, the under layer being horizontal of 1-inch square, and the outer vertical 1½-inch square, and each layer being strongly cramped into the granite, and the wall covered and surrounded by 12 ft. of earth. Cost £4 16*s*. 8*d*.

"The stone, iron, and convict labour for this work were given gratis by order of the Board, and the expense of coals and lime only charged, it being intended to try an idea of General Ford's, that wrought-iron bars would resist and break cast-iron shot.

"The experiment was made from a 24-pr. at 600 yds. distance, which, on striking the face of the iron-cased wall only nineteen times, had penetrated through both layers of bars, and pulverized the stone under them, so completely as to render further battering unnecessary."—Extracts from Books in the Royal Engineer Office, Woolwich. "Iron-cased Wall, Royal Arsenal, erected agreeably to Board's Orders of 12th April and 19th May, 1826, by convict labour."

Select Committee. The experiments carried on are so complete in themselves that any epitome of them would convey but a very imperfect idea. The whole of these experiments are in print, and I have no doubt, quite accessible to any artillery officer who may wish to read them.

The result, however, arrived at was, that a good wrought-iron plate $4\frac{1}{2}$-in. in thickness, backed with 18 inches of teak, is considered for all practical purposes proof against any ordnance not exceeding the 68-pr. or 100-pr. Armstrong, at a range of 400 yds.

During these experiments it was found that although, except in rare cases, ships of this construction were impenetrable, still, that penetration was at last obtained coupled with most terrible destruction if struck several times with heavy projectiles near the same spot. The shot on impact is broken in pieces, and carried through with the fragments of the iron and wood; the plate in this case not only not affording any protection, but materially increasing the destructive effect of the shot; on one occasion the number of pieces produced by a single shot were carefully collected, and it was found that there were over 700 pieces of wood and iron each of sufficient size to be formidable. The possibility of such destructive and alarming effects have led many to question the advantages of iron defences; but I think few except those whose sympathies are wedded to the romantic notion of "the wooden walls of England," would hesitate to prefer defence capable of resisting all missiles under ordinary circumstances,—defective only in the improbable event of several shot striking the same spot, to being exposed to the fire of Armstrong 100-pr. shell with $8\frac{1}{2}$ lbs. of powder, or Martin's liquid iron shell.

I have mentioned above the fact of these $4\frac{1}{2}$-inch plates being impenetrable except in rare cases; and as this exceptional case of penetration has been urged in favour of the Whitworth gun in preference to the Armstrong, I will enter more into detail on this matter than its importance might seem to warrant.

The long range obtained by Mr Whitworth induced the government to try the effect of his ordnance against armour plates, and it was found that his flat-headed projectile obtained greater penetration than others, and in one case punched a hole through both plate and wood, and fell on the deck inside. The plate although penetrated was not much damaged, and the actual advantage gained by the penetration was very little; for it must be borne in mind that this projectile was made of homogeneous iron, which did not break up on impact, and which from its cost could never be used except in an experiment. The punching action of this shot is not what is required to destroy armour plates; for little or no damage would be sustained by a ship having holes of such small diameter punched in her armour, as there would be no difficulty even in action in plugging them; and the shot having expended all its force in the penetration falls harmlessly on the deck.

At the conclusion of the experiments, orders were issued for the construction of the "Warrior," the "Black Prince," the "Defence," and the "Resistance," all of a similar construction, viz. $4\frac{1}{2}$-inch wrought-iron plates, $15' \times 3'\ 2''$ feet, fastened by $1\frac{1}{4}$-inch bolts; 18 inches of teak well caulked, $\frac{1}{2}$-in. wrought-iron skin on iron ribs 18 inches apart, the only difference being that, in the Warrior and Black Prince the centre part alone is plated with $4\frac{1}{2}$-inch iron, the bow and stern being con-

structed of ordinary $\frac{3}{4}$-inch boiler plate; this construction was adopted with a view of giving increased speed without increased displacement. It is doubtful even if the advantage gained in the increased speed obtained is not more than compensated by the disadvantage of having several of her guns so inadequately defended, that they could not be worked if fighting at close quarters; indeed, the thin coating of iron on bow and stern would greatly add to the destructive effect of the shot, as proved by some experiments carried on by Capt. Hewlett, C.B., H.M.S. Excellent, at Portsmouth, which shewed that all cast-iron shot are broken on impact with any wrought-iron plate $\frac{5}{8}$ths in. thick, and pass through the plate in fragments.

However, as the highest authorities differ on the important subject of sacrificing defence to speed, I will not presume to give an opinion.

The principal disadvantages in the construction adopted in these first iron ships, are as follows:—

(1) The through bolts by wounding the face of the plate render it liable to crack on being struck by a shot.

(2) The $1\frac{1}{4}$-in. bolt is not sufficiently strong for the purpose.

(3) The wood backing is liable to decay, and its renewal would be necessary from time to time at nearly half the cost of a new ship.

(4) The tongue and groove at the edges of the plates render it impossible to remove a plate if damaged, without bringing the vessel into dock, and even then it would be a work of great labour and expense; they also tend greatly to spread the destructive effect of a shot to the surrounding plates.

As it was considered desirable that some further experiments should be carried on to determine the best quality of iron for defensive purposes, a Committee was formed at the beginning of last year to ascertain whether it might not be possible by some improvement in the manufacture of armour plates to lessen the thickness of $4\frac{1}{2}$-inches, and also to devise some mode of attachment that would obviate the necessity of bolt holes, and the tongue and groove. The question of employing iron for land defences was also submitted for their consideration, as the Defence Commission had some idea of employing iron very largely in constructing the works at Spithead, Portland, &c. This idea gave rise to the experiments that were carried on with the Thorneycroft bars. As greater resistance to shot was obtained by these bars than by any other means, and as they are now being employed in the defences of Antwerp, the following history of their origin may be interesting:—

In the early stage of the inquiry relative to iron defences, it was found exceedingly difficult and expensive to obtain large forgings sufficiently sound to resist shot, until Mr Hartley, of the Shrubbery Iron Works, Wolverhampton, proposed to try the effect of rolled bars of iron tongued and grooved together; this proposal was agreed to, and Mr Hartley was desired to prepare a target with as little outlay as possible; he therefore adapted a pair of rolls he had in stock, and produced bars with a sectional area of 15×5 in., the size of

the rolls, or rather the chance selection of the pair used, determined the size of the first bars which obtained the name of Thorneycroft's bars, simply because they were made at the Shrubbery Iron Works, which were formerly more generally known by the name of Thorneycroft's. A target formed of these bars secured together, (in addition to the tongue and groove,) by a bolt passing through them, was found to offer such resistance to shot as to warrant the belief that if reduced to $10 \times 4\frac{3}{4}$-in., the defence would still be found sufficient. An embrasure was therefore constructed of bars $10 \times 4\frac{3}{4}$-inch having several feet of masonry above them; on this occasion, the bolt used in the former experiment to secure the bars together was dispensed with, as it was considered that sufficient solidity would be obtained by the weight of the masonry above. This embrasure stood the most severe tests without shewing any signs of weakness; salvoes from 68, 80, 40, and 32-pr. guns were fired against it, apparently without damaging the structure, and it was with reason thought that an embrasure of this construction was invulnerable. Indeed, so confident were all in this method of applying iron for defence, that it was proposed still further to reduce the sectional area of the bars, and to substitute wrought-iron supports for the masonry. Two embrasures were therefore constructed for experiment, one of bars $10 \times 4\frac{3}{4}$-in., supported by wrought-iron uprights $2\frac{1}{2}$ ft. apart, and every fourth bar secured by a dovetail at the back to the upright. The other embrasure was composed of bars $8 \times 3\frac{3}{4}$-in., supported at the ends by masonry, and in the centre by wrought-iron uprights $2\frac{1}{2}$ ft. apart similar to the other. At this experiment, Sir W. Armstrong's 120-pr. shunt gun was used, and the effect of this formidable piece of ordnance against the embrasures was such as to put an end at once to all idea of their impenetrability, and the strength anticipated by the wrought-iron supports. It was found that the tongue on the bars was readily stripped off, and the uprights broken in the vicinity of the blow, leaving, as it were, each bar singly to resist the impact of the shot without deriving any support from the others. In the bars used at this experiment sufficient care had not been taken in the "piling" to obtain the greatest amount of strength, but independently of this defect in manufacture, the very small comparative resistance offered to the shot caused all idea of using these bars to be most reluctantly abandoned. Bars of this description possess many advantages over wrought-iron plates, if it were possible to hold them securely together, and make each one derive its proper share of support from the others. The advantages alluded to are as follows:—

(1) The rapidity with which they can be manufactured.

(2) The facility of transporting them from the forge to the work.

(3) The great thickness of metal obtained sound at a comparatively small cost per ton, for it must be remembered that the price per ton of wrought-iron increases very rapidly in proportion to the weight: for example, while £19 per ton was paid for Thorneycroft's bars, with a prospect of a very considerable reduction, the armour plates were costing from £32 to £40 per ton, and the stern port of the "Warrior" cost no less than £150 per ton.

These bars however are not suited for ships of war, as it is by no means an economical form (as regards weight) of disposing the iron for defence. The weakest parts of an armour-plated ship are the joints of the plates: it follows then that the more these joints are multiplied, the weaker the structure becomes. To obtain, therefore, similar resistance with plates and bars, the latter must be considerably thicker than the former,—a most serious objection where weight is of such great importance.

The Committee appointed at the beginning of last year to continue the inquiry on the subject of iron defences, obtained the opinion of most of the principal iron manufacturers in the country as to the best quality and manufacture of iron to resist shot. The great diversity of opinion among so many practical men could only be accounted for by the fact that none of these gentlemen had ever had an opportunity of witnessing the effect of a shot on an iron plate, and this in some measure explains the very small progress that had, up to a recent period, been made in their manufacture. In consequence, plates of various qualities and manufactures were ordered for experiment, and the makers were requested either to be present themselves at the experiment, or to send some one in whom they placed confidence. They all most gladly availed themselves of this permission, and at the conclusion of the experiment they expressed themselves confident of being able to overcome all difficulties of manufacture, and of producing plates capable of resisting shot. Practical knowledge of great value was by this means afforded to those manufacturers who proposed to devote themselves to this branch of the iron trade; and a spirit of emulation raised among the different iron-masters which cannot fail to have a most beneficial effect in bringing the question (as far as qualities and manufacture are concerned) to a satisfactory solution.

The advantage of having allowed the iron manufacturers to be present at the different experiments is already becoming apparent in the improvement of the plates supplied for trial; and the time is not far distant when the more general use of mechanical means, to move the large masses while being forged, will reduce the price per ton to more reasonable limits.

These preliminary experiments determined the following points:—

(1) That steely iron, commonly known as homogeneous iron, puddled steel, &c., when in large masses, is inapplicable for defensive purposes; although in the thinner plates this metal offered great comparative resistance, it became brittle when in large masses, and readily cracked when struck by a shot.

(2) That plates of a hard crystalline structure are inferior to those of a soft fibrous nature.

(3) That the great fault and primary cause of weakness in all forged plates is unsoundness in welding the different piles of which the plate is composed. This defect was invariable in all (except the homogeneous iron plates); it was more apparent in the rolled than in the hammered plates, but this was compensated for by the hammered plates being harder and more crystalline than those forged under the rolls; and this led to the conclusion that there is but little choice between the two processes if both are properly worked out with efficient machinery.

(4) That the qualities necessary in an armour plate are softness combined with toughness, or better expressed by the word ductility. Apparently the purer and better the iron is, the more this quality is perceptible; any impurity or alloy appears to harden the metal, and produce brittleness, the presence of either sulphur or phosphorus in the fuel is specially to be guarded against as productive of red shortness and cold shortness in the iron. The presence of more than 0·2 per cent. of carbon in armour plates also appears highly prejudicial.

The opinion of all the witnesses examined appeared to be in favour of cold blast iron, to the entire exclusion of that produced by hot blast, apparently however not from any objection to the hot blast itself, but because by this process iron could be produced from the old cinder heaps and the inferior ores, and therefore offered a great temptation to some manufacturers to use the bad iron cheaply produced by this process instead of the better description produced by cold blast.

The great difficulty which now exists of obtaining a large forging homogeneous, will no doubt in a great measure be overcome when efficient machinery is employed; at present the manufacture of these large plates is being carried on (except in very few cases) with machinery never intended for forgings of one-half the weight, and few firms are prepared to sink the necessary amount of capital in "plant" to enable them to turn out sound forgings of great weight, unless larger inducements are offered to them.

Government would no doubt effect a very considerable saving by becoming their own manufacturers, and thus render the government inspectors at the different works unnecessary. It would also enable them to obtain a standard for sound and good plates.

The question of the best means of *applying* the armour to ships is one of very great difficulty. It seems at first sight nearly hopeless to attempt to produce a structure sufficiently strong to resist the modern artillery, and at the same time sufficiently buoyant to float; it is indeed doubtful, if a ship will ever be built so strong as to be quite invulnerable; but there is no doubt that ships will be constructed which may be said, for all practical purposes to be so*, and (what is in reality of far more importance) proof against decay. We may therefore look forward to some future time when we shall not have the dissatisfaction of seeing £500,000 yearly voted for repairs of the fleet, much of which is expended on ships which have never been in commission; to obtain this the fleet must be constructed wholly of iron, and experiments are now in progress to ascertain if sufficient strength can be obtained without the wood backing. No doubt if the wood is dispensed with, the effect of the shot will be considerably less on the armour plate itself, but it is yet an undecided question whether the vibration produced by the blow of the shot will not break the fastenings and start the rivet heads.

The question of the durability of iron ships when moderately cared for was proved by the state of the Peninsular and Oriental steam-ship "Ripon," after 16 years constant use, with no other protection to the iron than an occasional coating of red lead: the plates of this ship when taken off were found to be in perfect order, apparently not having suffered in the smallest degree

* This paper was in the Press prior to the experiments of 8th April, with the 300-pr. gun.

from the effects of the salt water, the only evidence of wear was in a few spots where the plates had been rubbed and worn by mechanical means. This vessel shortly after she was built was found to want permanent ballast, and it was thought the best way to meet the difficulty would be to build in between the ribs for about 15 or 20 ft. on each side of the keel with bricks covered with Roman cement. Several thousand bricks were used for this purpose, and remained where they had been laid until the middle of last year, when the "Ripon" was sent into dock to be lengthened. As these bricks had been 16 years without being moved, it was naturally thought that the plates under them might require renewing; it was found however on examination that the plates thus covered were with the exception of a thin coating of rust, as good and as sound as on the day they were made; the only plates that had suffered were those not protected by the covering, and even these were not harmed by corrosion, but were worn away by the friction of the bilge water and pieces of the bricks and cement which were detached by the rolling of the ship.

The great difficulty to contend against in iron ships is their liability to foul,—a serious disadvantage where speed is an essential quality. A variety of paints and oils have been proposed, but all have failed to prevent the collection of barnacles and weeds which always fasten upon a ship if not coppered. It was long supposed that copper prevented the accumulation of these parasites by means of its poisonous qualities, but it has since been proved that its efficacy is due to oxidation, which as it were mechanically detaches the barnacles and weeds; copper is however inapplicable to iron ships owing to the galvanic action that would take place unless the copper were perfectly insulated. Several methods have been proposed to effect this; the two most practicable have been recommended for trial, as experiment alone can determine their relative values; one of these methods, proposed by Mr John Grantham, is to rivet the ship's plates below water to the inside instead of the outside of the *timbers*, and to fill the intervals between them with hard wood; another layer of wood is then bolted to this with copper bolts, and the ship coppered in the ordinary manner. Objections have been raised on account of the plates of the ship being covered with wood, and so preventing any examination of the state of the rivets, and it was urged that corrosion might proceed to a dangerous extent without being discovered. Mr Grantham meets these objections by covering the ship's bottom with a very thick coating of bitumen and tar before fixing the first layer of wood, the joints of which are then carefully caulked, and the same process repeated after the second layer of plank is fixed; by these means he proposes to exclude any dangerous amount of moisture, and to make the exterior lining nearly if not perfectly water-tight; any moisture which might reach the plates under these circumstances would produce slight corrosion, but this would act rather as a preservative to the iron than otherwise.

The wood lining was also objected to from its liability to decay, but as the wood would certainly last as long as the copper, this objection can hardly be considered valid, as it would take but very little extra expense to renew the wood at the same time as the copper. Two vessels were built at Liverpool, and coppered on this plan 10 years ago; both appear to have been unfortunate, one was abandoned on the sand heads of the Hooghly,

and remained there several weeks, but was at last got off very little injured, owing to the protection afforded by the wood and copper, and is now said to be all right; the other was wrecked in the Java seas in 1859, but up to that time seems to have given the utmost satisfaction, so much so that the owner has expressed his intention never to have iron ships built in any other manner. A model of this plan, full size, may be seen at the Royal United Service Institution, Whitehall.

The other method of coppering ships is proposed by Mr Daft, who insulates the copper sheathing by a layer of india-rubber, the copper being fastened by small ebonite pins. A great objection to this plan is the necessity for perforating the plates to receive these small pins; the holes, although small, must weaken the bottom of the ship,—a grave objection in iron ships whose weak point is their liability to break up if they ground. Both these methods have been recommended for trial on a small scale, to determine their relative values; the absolute necessity however for some remedy for fouling may be gathered from an opinion expressed by Mr Watson, the managing director of the Holyhead mail packets:— "In one month after being cleaned they (the mail packets) lost speed, and in two months the loss amounted to from 10 to 15 minutes in the run, or about one mile an hour; this is caused by the weeds which collect on the ship's bottom." It may easily be imagined, if such a loss of speed is occasioned by fouling in vessels constantly in use between Holyhead and Kingston, what amount of speed would be lost by a ship lying at anchor for several months, in some port in the tropics as a guard ship.

Report of an Experiment carried on at Shoeburyness, on the 9th May, 1861, by the Special Committee on Iron.

MASONRY PROTECTED BY IRON.

THE object of the experiment was to ascertain what protection would be afforded to masonry by iron plates, 2, 2½, 3, and 3½ inches in thickness.

The experiment was commenced by firing a 12-pr. Armstrong cast-iron solid shot at a range of 600 yards. The projectile did not penetrate any of the plates nor cause any damage to the brickwork.

The 25-pr. land service Armstrong gun was next used, with cast-iron solid shot, at the same range. The projectile from the gun penetrated the 2-inch plates, but caused little damage to the other plates, and none to the masonry behind.

The 40-pr. Armstrong was next used, with cast-iron solid shot. The projectile penetrated all the plates, with the exception of the 3½-inch plate, on which it had hardly any effect at all; even when it penetrated the plates it did but very little damage to the masonry behind.

A 68-pr. 95 cwt gun was next used, with a charge of 16 lbs. and cast iron solid shot, at a range of 500 yards. The shot penetrated all the plates and damaged them a great deal; still the plates were not displaced, neither were the bolts started; it was remarkable that the bolts stood exceedingly well and prevented the plates buckling; the bolt holes were evidently a cause of weakness, as cracks almost invariably commenced there.

The number of shot of different rounds fired at these plates is as follows:—

12-pr. Armstrong	5
25-pr. „	16
40-pr. „	11
68-pr. „	10
Total	42

But the plates are still firm and in good order: and the wall is in as complete a state for defensive purposes as before the firing commenced.

May 16th.

The experiment was continued with a 100-pr. Armstrong gun, firing for the first 10 rounds shell filled with sand: weight empty $95\frac{1}{2}$ lbs., full 104 lbs.; charge 12 lbs.; then 4 rounds solid cast-iron shot from 68-pr. 95 cwt., with a charge of 16 lbs.; then 21 rounds, alternately 8-inch shell and 100-pr. Armstrong shell. With the 8-inch shell Pittman's naval fuze was used; with the Armstrong shell, the Pillar fuze. Every shell burst on striking. Range, 400 yards.

The 100-pr. shell filled with sand penetrated all the plates, except the $3\frac{1}{2}$-inch. The first shell that struck this plate did apparently no damage at all; it broke up, making a small indent on the plate; another, however, on striking near the same place, broke half the plate away and exposed the masonry.

After 10 rounds of 100-pr. blind shell and 4 rounds solid 68-pr. shot had been fired the plates were so damaged that live shell were used.

The live shell did very little damage when they struck the iron plate, not nearly as much as the blind shell, owing probably to its bursting before the whole of its force was expended on the plate; but when the live shell struck where the masonry was exposed they caused great damage, and soon brought the wall and surrounding masonry to such a state that a few more shell would entirely have destroyed it and the casemate next to it.

This experiment shews that masonry covered with 2-inch iron plates will effectually resist a 12-pr. Armstrong shot at 600 yards.

Covered with $2\frac{1}{2}$-inch plates, it will effectually resist a 25-pr. Armstrong shot, at 600 yards.

Covered with 3-inch plates, it will effectually resist a 40-pr. Armstrong shot, at 600 yards.

But the $3\frac{1}{2}$-inch plates are not sufficient to resist the heavier nature of projectiles.

The iron plates were manufactured of rolled iron by Messrs Brown Hughes, and Co., Newport.

5 feet 6 inches by 2 feet 6 inches,
4 feet 6 inches by 2 feet 6 inches, } 2, $2\frac{1}{2}$, 3, $3\frac{1}{2}$ inches in thickness.

Each plate was secured to the masonry by six 2-inch bolts which passed through the plate and were secured by double nuts to railway bars buried vertically 4 feet in the masonry; the top of these bars were again secured by bolts to the rear of the work.

May 9, 1861.

Nature of Ordnance.	Number of Round.	Projectile. Nature.	Projectile. Weight.	Projectile. Form.	Charge in lbs.	Elevation.	Range in yds.	Deflection.	Initial Velocity.	Effects. Depth of Indent in inches.	Effects. Area of Indent in inches.	Bursting charge of Shell in lbs.	Remarks.
			lb. oz			° ′		′					
12-pr	1	...	11·9	...	$1\frac{1}{2}$	1 4	600	4R	...	$\frac{1}{4}$	...	...	Hit right-hand corner of masonry; buried itself in the brickwork.
„	2	...	...	...	...	1 2	...	2R	...	$\frac{1}{4}$	...	...	Hit centre of $2\frac{1}{2}$-in plate; very slight indent; no cracks; shot broke.
„	3	...	...	...	...	1 0	...	2 L	...	...	...	...	Missed.
„	4	...	...	...	...	1 0	...	2 L	...	$\frac{1}{4}$	...	...	Hit left-hand top corner of 3-in. plate just over the bolt; one very small crack from bolt hole; indent very small; plate not hurt.
„	5	...	...	...	...	0 57	...	2R	...	$\frac{1}{4}$	...	...	Hit centre of 3-in. plate; very small indent; plate not damaged.
25-pr	6	...	$24\frac{11}{16}$	...	$3\frac{2}{16}$	0 56	...	2R	...	$\frac{3}{4}$	...	...	Short and ricochet. Hit 3-inch plate to left of left-centre bolt, half on plate, half on masonry; bolt slightly drawn out; plate bent a little but no damage done.
„	7	...	...	...	...	1 0	...	4R	...	...	...	...	Short and ricochet. Hit 2-in. plate with side of shot, just leaving the mark of its shape on the plate.
„	8	...	...	...	...	0 58	...	6R	...	$\frac{1}{2}$	...	...	Struck on the edge of the 3-in. plate near right centre bolt; made a circular crack through bolt hole; diameter of the cracked part 7 inches.
„	9	...	...	...	...	0 56	...	8R	...	$\frac{1}{2}$	...	...	Hit close to No. 8; very small indent; no cracks.
„	10	...	...	...	...	0 57	...	8R	...	$\frac{1}{4}$	...	...	Hit $3\frac{1}{2}$-in. plate near the centre; no damage to plate.
„	11	...	...	...	...	0 57	...	8R	...	$\frac{1}{2}$	...	...	Hit 4-in. from top of lower $2\frac{1}{2}$-in. plate; no damage done.
40-pr	12	...	40	...	5	0 58	...	4R	...	$\frac{3}{4}$	...	...	Hit at the join of the 3-in. plates; the left bolt slightly drawn, and the plate bent $\frac{1}{4}$-in., but not damaged.
„	13	...	...	...	...	0 .58	...	4R	...	6	...	...	Hit left top corner of the lower 2-in. plate; broke the plate; a piece 8 in. by 8-in. driven 6-in. into masonry; the bolts were not drawn, nor the plate shaken or cracked.
„	14	...	...	...	...	0 58	...	4R	...	...	...	...	Hit at junction of 2-in. and $2\frac{1}{2}$-in. plates; a piece 6-in. by 7-in. nearly broken out, driven 4-in. to masonry; the edge of $2\frac{1}{2}$-in. plate slightly bulged.
25-pr	15	...	$24\frac{11}{16}$	...	$3\frac{2}{16}$	0 57	...	8R	...	$\frac{1}{2}$	...	...	Hit centre of $3\frac{1}{2}$-in. plate; no damage.
„	16	...	...	...	...	0 57	...	8R	...	$\frac{3}{4}$	...	...	Hit centre of $2\frac{1}{2}$-in. plate; no damage done.
„	17	...	...	...	...	0 57	...	8R	...	$\frac{1}{2}$	...	...	Hit near centre of $3\frac{1}{2}$-in. plate; no damage.
„	18	...	...	...	...	...	...	...	...	$\frac{1}{2}$	...	...	Hit at junction of $2\frac{1}{2}$-in. and $3\frac{1}{2}$-in. plates; $2\frac{1}{2}$-plate driven in $\frac{1}{4}$-in.
„	19	...	...	...	...	...	...	...	...	$\frac{15}{16}$	...	...	Hit centre of $2\frac{1}{2}$-in. plate; no damage done.
„	20	...	...	...	...	...	...	...	...	$2\frac{1}{16}$	...	...	Hit lower 2-in. plate; made a large circular crack round the indent.
„	21	...	...	...	...	...	...	...	...	2	...	...	Hit lower 2-in. plate near bolt hole; two large cracks, one on each side of bolt hole, extending from it 6-in.
„	22	...	...	...	...	...	...	...	...	3	...	...	Large crack passing through the bolt hole near the indent and extending round it in diameter 12-in., plate much bent; the bolt hole evidently weakened the plate.
„	23	...	$24\frac{11}{16}$	...	$3\frac{2}{16}$	0 58	600	8R	...	...	...	...	Hit top of granite.
„	24	...	...	...	...	...	...	...	...	$3\frac{1}{2}$	...	...	Hit $2\frac{1}{2}$-in. plate 4-in. from the edge; the plate much cracked within and round the indent, in area 8 by 10-in.
40-pr	25	...	40	...	5	0 58	...	4R	...	...	...	...	Miss, short, and ricochet on to bottom of plate.
„	26	...	...	...	...	...	...	...	...	3	...	...	Hit lower left plate ($2\frac{1}{2}$-in). near left centre bolt, bulged the plate into masonry in area 6-in. by 7-in.; two cracks from the bolt-hole.
„	27	...	...	...	...	1 0	...	4R	...	...	...	...	Hit close to No. 25 at bottom of 3-in. plate, 2-in. from a bolt; drove a piece 12-in by 5-in. into the masonry 4-in. deep.
„	28	...	...	...	...	1 0	...	4R	...	...	...	...	Struck 300 yds. short and over target.
„	29	...	...	...	...	1 3	...	4R	...	...	...	...	Miss short.
„	30	...	...	...	...	1 5	...	4R	...	$\frac{1}{4}$	...	...	Hit lower $3\frac{1}{2}$-in. plate; damage very slight.
„	31	...	...	...	...	1 5	...	4R	...	$\frac{1}{4}$	...	...	do do do
„	32	...	...	...	...	1 5	...	...	...	$\frac{1}{4}$	...	...	do do do

	Number of Rounds.	Projectile. Nature.	Projectile. Weight in lbs.	Projectile. Form.	Charge in lbs.	Elevation.	Range in yds.	Deflection.	Initial Velocity.	Effects. Depth of Indent in inches.	Effects. Area of Indent in inches.	Bursting charge of Shell in lbs.	Remarks.
or	33	...	68	...	16		500	...	...	4	...	...	Struck 300 yds. short; hit top of 2-in. plate over top right-hand bolt; diameter of indent 9-in.; the corner of the plate buckled up 1½-in.; masonry started and cracked a little.
	34	...	...	...	...	...	...	...	...	8	7 by 11	...	Hit at junction of 2-in. and 3-in. plates; depth of indent 8-in.; area 7-in. by 11-in.; started masonry ¼-in. and cracked the granite block on the top; a crack from the bolt hole of 3-in. plate.
	35	...	...	...	...	...	...	...	...	...	...	...	Missed the target and hit Thorneycroft's embrasure close to its left edge, on the fifth bar from top; broke the bar and drove it 5-in. into the opening of the embrasure.
	36	...	...	...	...	...	...	...	...	5½	20by 9	...	Hit 2½-in. plate, crack extending from a bolt hole; a piece of the plate 20-in. by 9-in. driven into the masonry which was much shaken.
	37	...	...	...	...	...	...	...	...	6	12by 12	...	Hit at junction of 2½-in. and 2-in. plates which separated ¼-in.
	38	...	...	...	...	...	...	...	...	7	10by 10	...	Hit top of lower 3½-in. plate; crack through left upper bolt hole; it struck over No. 11.
	39	...	...	...	...	...	...	...	...	...	...	...	Hit top of stonework.
	40	...	...	...	...	...	...	...	...	6	12by 12	...	Hit at the junction of the two 3½-in. plates; the plates separated ¾-inch, crack extending from bolt hole to No. 32 shot hole; the bolts not a bit started.
	41	...	...	...	...	...	...	...	...	...	...	...	Hit corner of the granite and brought down a large piece.
	42	...	...	...	...	...	...	...	...	...	11by 13	...	Hit lower edge of 2-in. plate; shot broke up and remained in the hole 5-in. in masonry.
													May 16, 1861.
pr	1	shell	104	...	12	40′	400	7′R	...	...	...	Filled with 8½ lbs. of sand	Struck bottom corner of 2-in. plate on the top of the bolt, broke away a piece 15 in. by 9 in., and drove it broken up with the pieces of the shell 2 ft. into masonry; struck over No. 42.
,	2	...	...	...	...	48	...	10′R	...	...	...	do	Struck at the joint of 2½-in. plates, broke away an irregular hole 14 in. by 11 in., and forced the pieces with the shell 1 ft. into masonry; lower bolt very much damaged and bolt bent.
,	3	...	...	...	...	...	...	8′R	...	...	...	do	Hit junction of 2-in, plates; shell broke up and driven into the masonry about 15 in. deep; broke away the left corner of lower 2½-in. plate near last round; broke off 5 in. of the bolt where hit.
,	4	...	...	...	...	...	...	...	...	...	...	do	Struck joint of 3-in. plates; hole 9 in. by 12 in.; drove pieces with pieces of shell 10 in. into masonry; plate not cracked, very slightly bent; the plates slightly separated.
,	5	...	...	...	...	...	...	...	...	...	...	do	Struck 2½-in. plate near left edge over No. 24, broke away a piece 2 ft. by 9 in., and drove it in pieces with pieces of shell 1 ft. into masonry; plate much bent, no cracks.
,	6	...	...	...	...	...	...	9′R	...	...	...	do	Hit joint of 3½-in. plates over the 68-pr. No. 38; two large cracks extending through bolt holes in a circular direction right across the plate; another circular crack on lower plate through the port hole; did not penetrate.
,	7	...	...	...	...	...	...	...	...	...	...	do	Hit centre of lower 3½-in. plate, started a bolt 1 in.; plate very slightly bent; depth of indent very small indeed; plate not damaged at all; a great deal of masonry shaken down from top.
,	8	...	...	...	...	...	...	...	...	...	...	do	Hit near the same place; plate a very little buckled and cracked across; the bolts stood well, the plate being forced back on them; the crack passed through a bolt hole.
,	9	...	...	...	...	...	...	...	...	...	...	do	Hit centre of 3-in. plate; depth 3½-in.; large circular crack round indent: diameter of crack 14 in.

Nature of Ordnance.	Number of Round.	Projectile. Nature.	Projectile. Weight in lbs.	Projectile. Form.	Charge in lbs.	Elevation.	Range in yds.	Deflection.	Initial Velocity.	Effects. Depth of Indent in inches.	Effects. Area of Indent in inches.	Bursting charge of Shell in lbs.	Remarks.
68-pr	11	shot sol c.-iron	68	S*	16	½°	400	...	1557	...	...	...	Hit on the exposed part of masonry, on the place where the piece of plate fell off. Penetration 2½ ft. to shot; masonry much broken; shot not broken.
„	12	„	68	„	16	½°	400	...	1557	...	...	...	Hit just at edge of hole made by No. 5; shot broke up, increased the hole by a circle 9 in. in diameter.
„	13	„	68	„	16	½°	400	...	1557	...	...	...	Hit 3½-in. plate at edge of hole made by No. 5, increasing hole by a circular hole 9 in. in diameter; plates much separated; brickwork powdered to a depth of 14 in.; bolts near a little bent.
„	14	...	...	...	...	...	400	...	...	...	...	...	Hit Thorneycroft embrasure; depth of indent 1¾ in.; no damage done; diameter of indent 9 in.; no cracks at all visible.
100-pr	15	shell	104	A	12	48′	400	8′R	...	...	...	8½	Hit near No. 3; passed through the plate, and burst behind the plate, breaking away a large piece, making 3 and 2 into one hole; masonry much damaged behind.
68-pr	16	„	49½	Sc	16	½°	400	...	1746	...	...	1½	Shell struck near top of 3½-in. plate, broke away a piece 9 in. in diameter.
100-pr	17	„	104	A	12	48′	400	8′R	...	...	...	8½	Hit at junction of 2-in. and 2½-in. plates between Nos. 2 and 3, and near No. 15; damaged the masonry very much; the effect on the plate could not be seen, as it was so damaged by previous shot.
68-pr	18	„	49½	Sc	16	½°	400	...	1746	...	...	1½	Struck where the 3½-in. plate was broken away; broke off one bolt, and crumbled away the brickwork to a depth of 3 ft.
100-pr	19	„	104	A	12	48′	400	9′R	...	...	...	8½	Hit lower 3 in. plate about the middle; blew away half the plate, starting and bending all the bolts near, and undermining the whole centre of the plates.
68-pr	20	„	49½	Sc	16	½°	400	...	1746	...	...	1½	Hit at top of 2½-in. plate; broke away a large piece, undermined the plate.
100-pr	21	„	104	A	12	48′	400	9′R	...	...	...	8½	Hit in the hole made by the destruction of the upper part of 2½-in. and 3½-in. lower plates; increased the depth of the hole in the masonry; the plates were so damaged round here that the effect could not be ascertained.
68-pr	22	„	49½	Sc	16	½°	400	...	1746	...	...	1½	Hit nearly in the same place as last, increasing the breach in the masonry to a depth of 4 ft.; broke and bent the bolts all around.
100-pr	23	„	104	A	12	48′	400	9′R	...	...	...	8½	Hit nearly in the same place as the former shot; the plates and masonry were so damaged that the effects cannot be recorded.
68-pr	24	„	49½	Sc	16	½°	400	...	1746	...	...	1½	Hit left lower corner of upper 3-in. plate, bulged in the piece 2¼ in.; plate started forward ¼ in.
100-pr	25	„	104	A	12	48′	400	9′R	...	...	...	8½	Hit centre of target; broke away a piece of plate 2 ft. square with a bolt 4 ft. long attached to it; increased the hole in brickwork.
68-pr	26	„	49½	Sc	16	½°	400	...	1746	...	...	1½	Hit the granite to the left; split the granite block but did little other damage.
100-pr	27	„	104	A	12	48′	400	9′R	..	...	...	8½	Hit 3-in. plate, upper, near the centre; broke away the lower half, leaving the piece supported by one bolt; broke away and started the masonry round, and started the plates and brought down some more masonry.
68-pr	28	„	49½	Sc	16	½°	400	...	1746	...	...	1½	Hit the same place as last shot; increased the hole; cracked the masonry behind.
100-pr	29	„	104	A	12	48′	400	9′R	...	...	...	8½	Hit centre of 2-in. plate; knocked the whole iron face to pieces; the few pieces of plates remaining were merely hanging by the bolts; the railway bars and masonry behind them perfectly secure.
68-pr	30	„	49½	Sc	16	½°	400	...	1746	...	...	1½	Hit the left on the granite; did not do much damage.
100-pr	31	„	104	A	12	48′	400	9′R	...	...	...	8½	Hit bottom of 2-in. plate; passed through it and 1 ft. 8 in. into the masonry.
68-pr	32	„	49½	Sc	16	½°	400	...	1746	...	...	1½	Hit at the bottom among the debris of the masonry and did not much increase the damage.
100-pr	33	„	104	A	12	48′	400	9′R	...	...	...	8½	Hit near centre of target; broke away some more masonry.
68-pr	34	„	49½	S	16	½°	400	...	1746	...	...	1½	Short 20 yds; hit 3-in. lower plate; broke away a piece 9 in. by 11 in.
100-pr	35	„	104	A	12	48′	400	9′R	...	...	...	8½	Hit against the railway bars, broke one of them, and broke through the masonry, driving out a solid piece of brickwork 2 ft. square; the masonry much shaken and cracked behind; the arch of embrasure cracked nearly across in two places; some of the bricks driven 20 yds. in rear; the upper part of

THORNEYCROFT'S EIGHT AND TEN-INCH IRON BARS.

June 6, 1861.

The 1st target was formed of Thorneycroft bars, secured by dovetails to the iron uprights; the dovetails were rolled on the back of the 1st, 8th, 12th, 19th, and 21st bars. The bars were 10-in. by 4-in., and 12 ft. long; the iron uprights were $2\frac{1}{2}$ ft. apart.

The 2nd target was formed of similar bars, 8-in. by $3\frac{3}{4}$-in., supported in a similar manner with iron uprights, the end ones being supported by masonry.

The Thorneycroft Independent Shield, Bars 10 *in. by* 4 *in.*

No. of round.	Nature of Ordnance.	Charge, lbs.	Weight of Projectile, lbs.	Nature of Projectile.	Range, yds.	Elevation.	Deflection.	Remarks.
2	68-pr. 95 cwt.	16	$66\frac{1}{4}$	cast-iron round shot.	400	$\frac{1}{2}°$	...	Hit the right face just at the mouth of the embrasure on the 4th bar above the sill; made an indent 7-in. in diameter. Three of the bars driven back 3-in., two more bars 2-in. The tongue of the bars where struck sheared off.
3	...	...	...	...	...	...	...	Passed through the embrasure.
4	...	...	...	...	...	...	...	Struck the lower bar on its lower edge; scooped out a hemispherical piece $2\frac{1}{2}$-in. in depth, 7-in. in diameter; tore away some of the wooden foundation.
5	...	...	...	...	...	...	...	Struck 20-in. to the left of the last round. Exactly the same effect.
6	...	...	...	...	...	...	...	Hit the left top of the target on the 7th and 8th bar from the top; diameter of indent $9\frac{1}{2}$-in., depth $1\frac{3}{4}$-in. The back of the 8th bar which, owing to the dovetail on the back was $12\frac{1}{2}$-in. in thickness, was cracked. The bars did not appear to be displaced.
7	...	...	...	...	...	...	...	Through the embrasure.
8	...	...	...	...	...	...	...	To the right and 13-in. from the mouth of the embrasure on the 13th and 14th bars; diameter of indent 9-in., depth 1·64-in.
9	100-pr.	14	110	cast-iron	400	30′	6′R	Through the embrasure.
10	Armstrong	...	...	solid shot, hemispherical head.	...	38′	...	Hit the foot of the second upright below the bars; broke away $3\frac{1}{2}$ ft. of the bar, tore away the part that formed the dovetail between 19th and 21st bars, and drove the top of the target 6-in. forward.
11	...	...	...	...	...	46′	...	Struck the 5th bar from the top; diameter of indent $8\frac{1}{4}$-in., depth 1·68-in.; cracked the bar.
12	...	...	...	...	...	...	...	Hit the 10th bar from the top; opened a crack right through the bar one inch wide. The left upright was cracked right through at the second dovetail from the top. The tongue of the bar where struck was sheared off for several inches. Indent 2·12-in.
13	120-pr. shunt gun, muzzle loader.	18	126	cast-iron solid shot, hemispherical head.	400	33′	...	Hit the 3rd bar from the top; broke away 2 ft. 9-in. of the bar, and drove it ten yards to the rear of the target; opened the three top bars $1\frac{1}{2}$-in. each, stripped off the top part of the first dovetail on the second upright; opened the crack on the first upright $2\frac{1}{2}$-in wide. Indent 2·20 in.
								The target fell on its face.
The Thorneycroft Embrasure, supported by Masonry. The bars were 8 *in. by* $3\frac{3}{4}$ *in.*								
1	68-pr.	16	$66\frac{1}{4}$	cast solid	400	$\frac{1}{2}°$	...	Hit on the 3rd and 4th bar below the sill of the embrasure; drove a piece $7\frac{1}{2}$ by $4\frac{1}{4}$ by $2\frac{1}{2}$-in. from the back of the 3rd bar; diameter of indent on the face 9-in., depth 2-in.
2	...	...	...	...	...	...	...	Hit on the left of the embrasure on 17th, 18th, and 19th bars; made an indent 9-in. in diameter, $1\frac{3}{4}$-in deep, and cracked the bar.
3	...	...	...	...	...	...	...	Hit almost exactly on the same spot as No. 2, made a crack across all three of the bars $2\frac{1}{4}$-in. wide, the bars were driven $2\frac{3}{4}$-in. into the mouth of the embrasure. The masonry was much shaken.
4	100-pr.	14	110	cast solid	400	46′	6′R	Hit just over one of the iron upright supports, which it drove away, tearing away the slots made to receive the dovetails on the back of the bars, and breaking it into three pieces; cracked the bar where it

No. of Round.	Nature of Ordnance.	Charge, lbs.	Weight of Projectile, lbs.	Nature of Projectile.	Range, yds.	Elevation.	Deflection.	Remarks.
5	...	...	...	...	...	...	...	Drove a piece of the bar, 80 lbs. in weight, thirty yards to the rear of the target; hit just below on the next bar to No. 4; opened a crack 8-in. wide through both bars; drove the ends of the bars $5\frac{1}{2}$-in. across the mouth of embrasure; knocked down the four top bars and cracked the masonry. Indent 3·1-in.
6	...	...	...	...	400	46′	6′R	Hit the bar which formed the top of the mouth of the embrasure at its extreme end, just over the wood backing, which it crushed in, made a small indent, and brought down six more bars. The target was now so destroyed that the firing was discontinued, and the 120-pr. shunt gun was laid on the old 10-in. Thorneycroft embrasure. Indent 2·00-in.
7	120-pr.	18	126	cast solid	...	...	...	Hit to the right and below the mouth of the embrasure; cracked three bars through in five places, opened the bars $1\frac{1}{2}$-in.; the bars were much bulged and distorted in rear. Indent 3·3-in.

The experiments continued against the Independent Shield of Thorneycroft bars, 10-in. by 4-in., and against the Embrasure formed of Thorneycroft bars, 8-in. by $3\frac{3}{4}$-in., were resumed 13th June, 1861. Range 400 yds., cast-iron solid shot.

Both the bars were secured by strong iron braces, and strongly supported by timber beams, but no backing was used.

No. of Round.	Nature of Ordnance.	Charge in lbs.	Weight of Shot, in lbs.	Elevation.	Deflection.	Remarks
1	100-pr	14	110	47′	3′R	Hit the top bar of the mouth of the embrasure, and passed through, scooping out a very small piece.
2	120-pr	14	$125\frac{1}{2}$	40′	2′L	Breech-loading shunt gun.—Hit on the 7th and 8th bars; depth of the indent 1·65 in., diameter of indent $9\frac{1}{2}$-in. The bar slightly bent behind: the tongue of the 6th bar sheared. The bars were separated $\frac{1}{4}$-in. in rear
3	120-pr	18	$125\frac{1}{2}$	30′	5′R	The muzzle-loading shunt gun.—Hit on the 18th and 19th bars; depth of indent 1·9-in. No crack or bulge in rear; the bars did not separate; the upper dovetail on the left upright started $\frac{1}{4}$-in.
4	100-pr	14	$110\frac{1}{2}$	47′	5′R	Hit on the 18th and 19th bars; depth of indent 1·3-in. No bulge behind, damage being slight indeed in rear.
5	120-pr, breech-loading shunt gun	14	$125\frac{1}{2}$	42′	2′L	Hit on the 10th bar; opened a crack 1-in. wide, broke off 13-in. of the bar and drove the bar 3-in. to the rear; sheared off the tongue. Struck over the 3rd upright from the left; knocked it off, tearing off the dovetails, broke the upright into two pieces; opened the bars, bulged them 3-in. to the rear, cracked the 13th bar lengthways.
6	120-pr.	18	$125\frac{1}{2}$	32	5′R	Struck over the left brace which was $1\frac{3}{4}$-in. in thickness: cut it in two; started the dovetail at the back of the left upright to $1\frac{1}{4}$-in.; broke the upright; cracked the bar across the back.
						The Embrasure formed of Bars 8 in. by $3\frac{3}{4}$ in.
7	100-pr	14	110	47′	5′R	Hit on the 6th and 7th bars; drove them 2-in. to the rear, cracked them through and drove away the two uprights; broke one into two pieces; tore away the dovetails from each.

No. of Round.	Nature of Ordnance.	Charge in lbs.	Weight of Shot, in lbs.	Elevation.	Deflection.	Remarks.
8	120-pr, breech-loading shunt gun	14	125½	42′	2′ R	Hit on the right wood support; passed through the 6-in. of wood, indented the iron 1·75-in.; broke the iron upright in rear in two places.
9	120-pr	14	125½	42′	2′ R	Tore away 4 ft. of four bars; sheared off the tongues; made a hole 4 ft. by 2½ ft. by 1¼ ft., beside the embrasure, drove several pieces to the rear. These two shot hit at the same time, and struck near together.
...	100-pr	14	110	47′	2′ R	
10	120-pr	14	125½	42′	3′ R	These four guns were fired together, they all struck, except the 68-pr., which passed through the embrasure, and the 100-pr., which struck the masonry.
	120-pr	18	125½	31′	3′ L	
	100-pr	14	110	47′	5′ R	
	68-pr, 95-cwt.	16	67	½°	...	The 7th and 8th bars cracked through; broke 6th, 8th, 9th bars across in two places and bulged them all inwards. The two shot that struck the embrasure were 5½ ft. apart.

THE "WARRIOR" TARGET.

The following Experiment was carried on at Shoeburyness, on 21st Oct., 1861, to determine the resisting powers of the "Warrior:"—

A target was constructed exactly similar to a midship section of the "Warrior:" length 20 ft., height 10 ft., with a port-hole in the centre.

This target was strongly supported by timber, at the same angle as the side of the ship, and was fired at with the following guns. Range 200 yds.

One 120-pr. muzzle-loading shunt gun.
Three 100-pr. breech-loading Armstrong guns.
One 68-pr. 95 cwt. gun.
One 68-pr. 112 cwt. gun.

The following shot and shell struck the target:—

From 120-pr. gun,

Solid shot ... 2, weight 140 lbs. each.

From 100-pr. guns,

Solid shot 6, weight 110 lbs. each.
Shell ...... 6, " 104 "
Solid shot ... 6, weight 200 lbs. each.
Solid shot ... 1, " steel

From 68-pr. guns,

Solid shot 4, weight 66¼ lbs. each.
Shells .... 4, weight 49½lbs. each.

No. of Round.	Nature of Ordnance.	Charge, lbs.	Nature of Projectile.	Weight.	Indent in Inches.	Remarks.
1	100-pr	12	shell filled with sand.	104	...	Hit on upper plate; made very slight indent; opened the plates ⅛ in.
2	"	"	"	"	...	Hit close together on the centre left plate; made a small crack 5 in. in length.
3	"	"	"	"	...	
4	68-pr	16	"	49½	1·5	Hit on upper plate, 7 in. from the edge; opened the plates ¼ in., and started two bolts very slightly.
5	"	"	"	"	"	Hit centre of left middle plate 3½ ft. from port, 7 in. from a bolt, which it drew a ¼ in.; broke the two bolts close to the port, and buckled the plate ⅜ in.
6	100-pr	12	shell filled with powder	104	...	Hit on junction of lower and centre plate; did no damage.
7	"	"	"	"	...	Hit upper plate; did no damage.
8	"	"	"	"	...	Hit centre plate; did no damage.

No. of Round.	Nature of Ordnance.	Charge, lbs.	Nature of Projectile.	Weight, lbs.	Indent in Inches.	Remarks.
9	68-pr	16	shell filled with powder	$49\frac{1}{2}$	1·8	Hit on upper plate over No. 1; tore up 4 ft. of tongue and groove, and cracked the plate in two places; cracks 7 in. long; drew the bolt $\frac{3}{4}$ in.
10	,,	,,	,,	,,	...	Hit on centre plate; cracked it in four places near; the cracks very small.
11	120-pr	20	solid cast-iron shot.	140	3·1	Hit on right-hand corner of the top plate; plate deflected $1\frac{3}{4}$ in.; the bolt, however, only stretched, and did not break. The right rib very slightly bent.
12	100-pr	14	,,	110	1·6	Hit close together; made a small crack across one indent, the plate driven back on a bolt 1 in. The plate now deflects nearly 2 in.
13	,,	,,	,,	,,	1·9	
14	,,	,,	,,	,,	1·3	
15	68-pr	16	,,	$66\frac{1}{4}$	2·7	Hit 18 in. from the three 100-prs.; one crack 7 in. long near the indent; two bolts broken near the port-hole. The centre right plate deflected 1·2 in.
16	100-pr	10	,,	200	...	Indent too small to be measured; no damage apparent. The three shots hit close together.
17	,,	,,	,,	,,	...	
18	,,	,,	,,	,,	...	
19	,,	,,	,,	,,	...	These three shots were fired in salvo. Struck close together on the right centre plate; the indent on plate very slight indeed. The plate buckled forward $\frac{3}{4}$ in. more. The tongue and groove broken for $2\frac{1}{2}$ ft.
20	,,	,,	,,	,,	...	
21	,,	,,	,,	,,	...	
22	68-pr	16	solid shot	$66\frac{1}{4}$	2·25	Hit near the port-hole, and buckled the plate $\frac{1}{4}$ in.
23	120-pr	20	,,	140	...	Fired in salvo three 100-prs. Hit close together $2\frac{1}{2}$ ft. from the port-hole; broke a hole $1\frac{1}{2}$ ft. by 9 in.; one large crack extended across the plate, two other smaller ones near it. 120-pr. hit on the junction of the centre and lower plates, made an indent $4\frac{1}{4}$ in. deep, $9\frac{3}{4}$ in diameter; broke the tongue and groove, and buckled the plate $1\frac{1}{4}$ in. forward. One 68-pr. missed the target; the other struck the lower plate on the left; made an indent 2 in. deep $8\frac{1}{2}$ in. in diameter. The back of the target was not at all damaged; not a bolt or rivet displaced.
24	100-pr	14	,,	110	...	
25	,,	,,	,,	,,	...	
26	,,	,,	,,	,,	...	
27	68-pr	16	,,	$66\frac{1}{4}$	...	
28	,,	,,	,,	,,	...	
29	100-pr	16	steel jacket-shot, flat headed.	...	3·3	Hit the middle of the left centre plate on top of a bolt; drove it nearly out at the back; the bolt was bent, but the nuts did not move; eleven shots had previously struck the plate in a space 3 ft. by $1\frac{1}{2}$ ft., viz.:— Three 200 lb. solid shot. Three 100 lb. ,, Three 100 lb. shells. Two 68 lb. ,,

THE "COMMITTEE" TARGET.

Experiment carried on 4th March, 1862, against a Target proposed by the Special Committee on Iron, constructed by Messrs Fairbairn and Co. of Manchester.

The target (20 × 10 ft.) was composed of two plates $20' \times 3' 4'' \times 4\frac{1}{2}''$, and two plates of $9' \times 3'4'' \times 4\frac{1}{2}''$, the upper and lower of which were secured by fifteen 2″ bolts, and the two centre by eight 2″ bolts each.

The armour-plates were fastened to 1″ plates, which latter formed the skin of the ship, which was supported by ribs 18″ deep, and 18″ apart, made of $\frac{7}{8}''$ plates secured by angle irons $4'' \times 4'' \times \frac{3}{4}''$; the back of the ribs were secured by four strips of plate $12'' \times \frac{1}{2}''$.

Strips $10' \times 9'' \times \frac{3}{4}''$ were behind the skin along each line of bolts.

The armour-plates were rolled by Messrs John Brown and Co., Sheffield.

The object of the experiment was to determine whether wooden backing can be dispensed with. The "Committee" target was therefore constructed, with the view of comparison with the "Warrior" target.

"Committee target," area 200 square feet; weight 31 tons.
"Warrior target," area 200 square feet; weight, 32 tons 9 cwt. 3 qrs.

The guns used were the same as against the "Warrior" target, viz.:—

One 120-pr. muzzle-loading shunt gun.
Three 100-pr. breech-loading Armstrong guns.
One 68-pr. 95 cwt. gun.
One 68-pr. 112 cwt. gun.

Range, 200 yds.

The following shot and shell struck the target :—

From 120-pr. gun,

Solid shot .... 1, weight 140 lbs.

From 100-pr. guns,

Solid shot........... 3, weight 110 lbs. each. | Shell .... 6, weight 104 lbs. each.
Solid Shot........... 3, weight 200 lbs. each.

From 68-pr. guns,

Solid shot........... 1, weight $66\frac{1}{4}$ lbs. each. | Shell........ 4, weight $49\frac{1}{2}$ lbs. each.

No. of Round.	Nature of Ordnance.	Charge.	Nature of Projectile.	Weight.	Indent in Inches.	Remarks.
1	100-pr	12	shell filled with sand.	104	...	Hit centre plate to the left of port-hole, about 9 in. from bottom of the plate; very slight indent. Diameter of bulge, 5 in.
2	"	"	"	"	...	Hit left centre plate 18 in. from bottom and about 5 ft. from left; indent very slight.
3	"	"	"	"	...	Hit left centre plate about 12 in. from top; slight indent. Diameter of bulge, 3 in.
4	68-pr	16	"	$49\frac{1}{2}$	1·4	Struck left centre plate 17 in. from bottom, and close to No. 2 round. Diameter of bulge, 8 in.
5	"	"	"	"	1·5	Hit left centre plate about 18 in. from bottom, and close to the 4th round. Diameter of bulge, $9\frac{1}{2}$ in.
						At the conclusion of the 5th round, the target was inspected. The left centre plate had buckled $\frac{3}{4}$ of an inch; two bolts in bottom plate, and two in centre plate, and one in top plate, started. Eight bolt-heads were broken off; one rib broken through, and two rivets of angle-irons knocked out. Two angle-irons broken. The bolts were slackened after this round.
6	100-pr	12	shell filled with powder	104	...	Struck on junction of middle and upper plate, 2 ft. 2 in. from left edge of target. The middle plate started forward.
7	"	"	"	"	...	Struck 2 ft. 5 in. from left edge of target, making an indent 7 in. in diameter.
8	"	"	"	"	...	Struck about 6 in. from the top edge of the target, near the bolt over port-hole.
9	68-pr	16	"	$49\frac{1}{2}$	1·14	Struck middle plate on left of port, and 2 ft. from it. Diameter of indent, 10 in. Bolt just above indent started.
10	"	"	"	"	1·26	Struck on junction of middle and upper plate, 16 in. from port. Diameter of indent, $9\frac{1}{2}$ in.
						The target was carefully examined after the 10th round, and it was found that all the bolts in the middle plate on the left of the target were broken, except the two nearest the port. The buckling was 1·7 in. at the left edge of the plate. The top plate had also started forward 0·4 in. at edge of target. At the back, the inner angle-iron by port on left side, and one rib were broken, two rivets driven out, and several started. The skin bulged. No cracks visible on any of the indents.

No. of round.	Nature of Ordnance.	Charge, lbs.	Nature of Projectile.	Weight, lbs.	Indent in inches.	Remarks.
11	120-pr	20	solid cast-iron shot.	140	...	Struck junction of right centre plate with top plate, at about 3 ft. 10 in. from port.
12	100-pr	14	"	110	...	Struck the bottom of upper plate, close to No. 11 round.
13	"	"	"	"	1·9	Struck centre of right centre plate.
14	"	"	"	"	...	Hit target close to 12 and 13 shots, and went clean through the target, carrying a large piece of the plate, part of the rib (on which the shot struck), and pieces of angle-iron 10 or 12 yards to the rear. The fracture measured in front of the target 1 ft. by 7 in. on the middle plate, and 5 in. by 3 in. on the upper plate. There was also a curved crack, 14 in. long, round the edge of the bulge, and through a bolt-hole.
15	68-pr	16	"	66¼	1·8	This shot struck within 5 in. (from centre to centre of indent) of the 13th round. The middle plate was bent back 1·6 in. at its lower edge. One bolt was knocked out, and two started. Middle plate started forward at right edge of target 0·65 in., and the upper plate similarly 0·2 in. At the back of the target, seven bolt-heads broken and one rivet. Two ribs broken through, and several rivets of angle-irons started.
16	100-pr	10	"	200	0·4	These three shot struck the left middle plate of target in a line, measuring only 16 in. from centre to centre of outside indents. The shot nearest to the port was 8 in., and the one furthest from, 15 in. from the lower edge of plate; the former was 2 ft. 4 in. from port, and the latter only about 4 in. (centre to centre) from No. 4 round.
17	"	"	"	"	0·5	The plate bent back 1·2 in. at its lower edge, at a point 2 ft. 9 in. from the port, and had started forward at left edge 6 in. from skin. Another angle-iron broken, and only three bolt-heads remaining on left side.
18	"	"	"	"	0·7	At the conclusion of this round, the target was considered so much injured that the experiment was ordered to cease.

REMARKS ON THE SYSTEM OF ORDNANCE CALCULATED TO PROVE THE MOST EFFICIENT AGAINST IRON CLAD SHIPS AND BATTERIES.

By Lieut.-Colonel BOXER, R.A., F.R.S.

SUPERINTENDENT ROYAL LABORATORIES, ROYAL ARSENAL, WOOLWICH.

Sufficient experiments have not yet been made, to determine the penetration of Rifle projectiles into the different materials employed in the construction of ships and land batteries; or, to ascertain the circumstances under which the new system of artillery will have advantages over the old in respect to penetration. Still we may learn much by a due consideration of the general principles which govern the motions of, and effects produced by, projectiles whether rifled or otherwise; and, indeed, enough to shew conclusively that—so far as concerns the effective power of artillery against that new mode of construction which must eventually supersede all others, namely, the employment of wrought-iron plates to cover ships and permanent land batteries. The arrangement carried out in smooth-bore ordnance, *in respect to the proportional weights of charge and projectile*, will be found superior to that adopted with rifle guns.

It is not necessary to enter into any elaborate investigation of the subject, in order to prove what is here advanced; and the following simple explanation may perhaps serve to elucidate sufficiently this important problem.

It may be fairly assumed, that to engage a properly constructed iron-clad battery with any reasonable chance of success, the attack must be made at very close quarters; in fact, at a range where, practically, little or no advantage would be gained by the use of rifled ordnance in respect to accuracy of fire and retardation by the resistance of the atmosphere. It remains, therefore, only to be considered, what combined arrangements as regards charge, weight of projectile, and diameter of bore, will be most effective against the opposing shield *under these circumstances.*

Although no definite limit can, at present, be laid down, either as to the weight of the gun, the intensity of strain to be resisted, or the amount of recoil, still there must be a limit in relation to all these particulars, which it would not be advantageous to exceed.

Let it be assumed for the sake of argument that, under all the circumstances attending the manufacture and service of the gun, the following is the maximum that can be allowed:—

(1) Ten tons for weight of gun.

(2) Such a strain as would be produced by projecting a sphere of iron weighing 150 lbs. with a charge of 50 lbs. of powder, and

(3) A recoil in the gun equal to that due to the above weights of charge and shot.

The desideratum is, to produce the desired results in the simplest, most effectual, and economical manner, with those means which are likely to be

generally available; and in comparing one system with another it is absolutely necessary that certain conditions should be made common to both. For instance, in considering the smooth-bore and rifle systems, due advantage must be taken, in both cases, of the most approved method of manufacturing the guns; also, the weights and recoil of the guns, as well as the strain or rather tendency to rupture the material of the guns at the discharge must be made equal.

Now,—will anything be gained under the above conditions by applying, in the case in question, the principle followed in all rifle guns (a principle upon which their success has been hitherto chiefly owing) of using elongated shot with a reduction in the charge of powder equivalent to the increased strain and recoil due to the additional weight of projectile?

This question, and it is a very important one, must be viewed entirely with reference to the "work" required to be done to penetrate or destroy the protecting shield.

The term "work done" denotes a certain pressure exerted through a certain distance. It is measured simply by the product of the pressure and the distance through which this pressure acts. The element *time* does not necessarily enter into the expression.

In the case under consideration, the "work done" upon the shot at the discharge of the gun is measured,

(1) By the intensity of the pressure of the exploded powder;

(2) By the amount of sectional area of shot upon which the pressure acts, and

(3) By the distance through which the pressure acts, namely, the length of bore, or nearly so.

So that in order that the same amount of "work" may be done on the elongated projectile as on the spherical shot, they must both be fired with equal charges. And, speaking generally, provided equal charges are used and the conditions as regards diameter of bore, windage, &c. are the same, no increase or diminution of "work done" on the shot will result from any variation in the weight of projectile.

But, by a fundamental principle of mechanics, the work done upon the opposing shield and shot on impact, will be equal to the work done on the projectile by the charge of powder in the gun, (leaving out of account the resistance of the air, which may be done when the range is short); therefore, in order to produce the same effect as regards "work" upon the opposing shield, apart from other considerations which will be noticed hereafter, the elongated rifle shot must be fired with the same charge as the spherical projectile.

If the same charge, however, be used with the elongated shot as with the spherical, namely, 50 lbs., the recoil of the gun, as well as the strain tending to rupture the gun will exceed the limits allowed in the particular case before us. For both recoil and strain depend directly on the *momentum* of the shot and not upon the "*work done*" to produce that momentum. In fact, *time* which affects both recoil and strain does not necessarily enter into

the expression denoting "*work*," namely PS,* but is a necessary element in that which is a measure of momentum, namely Pgt.†

For instance, suppose the elongated shot weighs 300 lbs. instead of 150 lbs. which is the weight of the spherical projectile. Then, as the average pressure on the two shot may be considered the same, when equal charges are used; if M equal the momentum of the 150 lb. shot, the momentum of the elongated shot will be $1{\cdot}4M$, and if t be the time of action of the powder on the gun in the former case, $1{\cdot}4t$ will represent the time of action in the latter, namely, when the elongated shot is fired; therefore, in order to bring the strain and recoil within the assumed limits, the charge must not exceed 25 lbs. of powder when a 300 lb. shot is used, and, if the 300 lb. shot be discharged with a greater charge than 25 lbs. of powder, the effects produced on the opposing shield by the two projectiles, namely, the 150 lb. and the 300 lb., will afford no criterion as to the relative merits of the two systems of ordnance in respect to penetration at moderate ranges.

And if the charge be reduced so as to fulfil the two essential conditions as regards recoil and strain, the "stored-up work" (if the expression may be used) in the shot will be diminished in a corresponding degree, namely, by one-half.

It is quite clear therefore that so far as "work done" on impact is concerned any increase in weight above the sphere must be positively disadvantageous within certain limits of range.‡

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* P=average pressure acting upon the mass, S=distance through which this pressure acts.

† P=average pressure acting upon the mass, g=32 or velocity generated by gravity in one second, t=time during which the average pressure acts.

‡ In any experimental investigation of the subject, this principle must be duly recognized, or the most erroneous conclusions are likely to be drawn from the results of the trials.

For instance, in the late trials at Shoeburyness against iron-plated targets it would be incorrect to measure the relative values of the two systems under consideration—namely, the light shot with the large charge, and the heavy shot with the small charge—by the effects produced on the targets; for the following Table will shew that the momentum of the shot, and therefore the strain on the guns and recoil were unequal:—

Nature.	Weight of projectile.	Charge.	Momentum, about	Remarks.
	lbs.	lbs.		
68-pr. iron gun	67·5	16	106,650	
110-pr. Armstrong gun	110·0	14	133,100	
" " "	200·	10	151,680	
120-pr. shunt gun	140·	20	170,240	

However, the results obtained in these trials—although they cannot be taken to measure the relative values of the systems—practically demonstrated the great advantage in respect to penetration at moderate ranges, of the light shot and heavy charge over the heavy shot and light charge; for, notwithstanding the comparatively small momentum of the 68-pr. shot, namely 106,000, it had nearly, if not quite as much effect on the target as the 140 lb. shot with a momentum of 170,000; and although the 200 lb. shot discharged from the 110-pr. with a charge of 10 lbs. of powder had a momentum of 151,000, it only indented the iron to a comparatively very small extent.

But independently of what has been stated, it is a question, whether, even if the "stored-up work" in two shot of the same diameter but of different weights be equal, the light shot from its greater velocity, would not be more *effective* in penetrating a material such as wrought-iron, than the heavy projectile, on account of the work being less distributed over the shield with the former than with the latter.*

There is however one important consideration which may, perhaps, give the system of rifle ordnance an advantage over that of smooth-bore and spherical shot even at short ranges. This consideration has reference to the form of that part of the projectile which first comes in contact with the opposing material and to the particular distribution of the metal of the shot. If the object be to pierce through the iron armour with the least expenditure of "work," it would manifestly appear advantageous to *cut* rather than break through (the reason of this is sufficiently obvious). Now this can, to a great extent, be accomplished with *rifle projectiles* by making the head of the shot, in the form of a punch, which has been actually done by Mr Whitworth with satisfactory results.

Again, it may be possible so to distribute the material in a rifle projectile that it shall have an advantage over the spherical form with respect to the "work done" on impact, on the *projectile itself;* this is an important point, for the "work" actually absorbed in the striking body, that is to say, the "work" equivalent to the permanent injury sustained by it, is lost so far as regards the opposing shield.

Although elongated shot, that is, shot greater in weight than the sphere of the same diameter, have been hitherto universally used with rifle ordnance; still, with proper arrangements, in respect

(1) To the degree of spiral in the bore,

(2) To the material used in the manufacture of the projectiles;

(3) To the proportional weights of charge and shot, combined with the sectional area acted upon by the exploded charge;

(4) To the form of the front part of the shot; and lastly, to the particular distribution of the material in the shot,—the rifle system may have advantages over smooth-bore ordnance as regards penetration, even at short ranges.

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* In considering the effect of projectiles upon a material like wrought-iron, which offers so much greater resistance to penetration than an ordinary material as earth or masonry, we must bear in mind that, although, two projectiles of different weights will have equal effects on the target in respect to the product of the resistance overcome, into the distance through which the resistance acts on the impinging bodies, if there be the same amount of "stored-up work" in each; still there may be more destructive effect produced by the one shot than by the other, for "time" is an important element as regards destructive effect, particularly when the material has great elasticity and tenacity. In the case which has been considered, namely, the 150 lb. shot and the 300 lb. shot discharged from the same gun with equal charges, and where the "stored-up work" is consequently the same in each, the heavy shot was longer in acquiring the "stored-up work" than the light shot, in the proportion of about 1·4 to 1, and the same resistance being offered when the two projectiles impinge on the target, the 300 lb. shot will therefore be a longer time in its action upon the target than the 150 lb. shot; under these circumstances the effect of the former will be extended over a larger area of the material than that of the latter, and may not, in certain cases, produce so much destruction.

But, if sufficient penetration can be obtained with a spherical shot, no doubt it would cause more destruction on board the ship than the projectile which punches or cuts its way through, for the same reason that the shot with a comparatively small velocity is more effective against a wooden ship, at short ranges, than one fired with the full service charge; and, it is quite clear that, if the desired effects can be produced with smooth-bore ordnance under those circumstances, which it is reasonable to expect will arise in actual warfare, it would be most unwise to adopt the more complicated, expensive, and delicate system of rifle guns.

Circumstances, however, may often arise under which the arrangements shewn to be defective when applied to a particular service, will produce better results as regards penetration, than those carried out in smooth-bore ordnance, and will prove, in other respects, most valuable. For instance, when the range exceeds a certain limit, the elongated shot will, from the comparatively small area acted upon by the opposing atmosphere, lose less of its "stored-up work" than the spherical projectile.

If, therefore, a system of ordnance could be devised combining the advantages of both, there could then remain no question as to its general introduction, but until this is fully accomplished (as it has been in the case of small arms), there will exist great differences of opinion, not as regards its employment for special purposes, but as to the desirableness of its *general* use.*

When two systems have to be compared, each of which has, with regard to the other, its advantages and defects, it would be unreasonable to expect that all should agree in estimating the amount of value to be attached to any particular quality, or as to what extent any defect would be likely to operate prejudicially.

Some are so dazzled with the brilliant quality of the rifle gun in respect to accuracy of fire at long ranges, that they fail to give due weight to the existing defects of the system.

There are others who consider that the degree of probability of striking a given small object at a long range under certain favourable circumstances is not, by any means, the principal test by which the real efficiency of a military weapon is to be decided, as perhaps success may depend on an amount of care and attention in the service of the gun exceeding that which will, as a rule, be bestowed; and that although a gun may be capable of projecting a shot truly to a very long range, circumstances may seldom occur where such a quality can be made available; and further, that the great difficulty amounting almost to an impossibility of judging the distance to the required nicety, when the range is even moderate, reduces the relative value of this property very considerably.

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* We have at present no gun in the British service sufficiently powerful to operate effectually against a properly constructed iron-clad battery. Under these circumstances there can be, it is imagined, but one opinion as to the vital importance of arming, with all possible dispatch, our ships and coast batteries with guns capable of penetrating at moderate ranges, iron-clad ships of war.

Whatever opinions may be entertained, as to the probability of our ultimately obtaining a rifle gun with an elongated shot which shall be more effective against ships constructed on the new principle, than a smooth-bore gun with a spherical projectile, a considerable time must elapse before this point can be decided; and as any delay may prove disastrous, it would indeed, in my opinion, be folly not to take immediate advantage of the arrangement which has been shewn, both theoretically and practically, to be the most efficient, and which can be made at once available.

If an absolute or definite value referred to some common standard, could be attached to each of the several qualities which enter as elements into the investigation, the subject would be capable of exact demonstration; but as this cannot be done, differences of opinion will exist until the problem is practically solved by the experience only to be derived from actual warfare, under all the varied circumstances attending it. Still there are points which do not reasonably admit of any differences of opinion, for they are based on fundamental laws, the truth of which cannot be questioned,—and it has been my sole endeavour, in writing these few remarks, to explain in a familiar manner, how the subject under discussion, is affected by these principles.

ANNUAL REPORT

AND

ABSTRACT OF PROCEEDINGS OF A GENERAL MEETING OF THE ROYAL ARTILLERY INSTITUTION, HELD ON TUESDAY, MAY 20, 1862.

MAJOR-GENERAL SIR R. J. DACRES, K.C.B. IN THE CHAIR.

The Committee of the Royal Artillery Institution have the honor to present to the Annual General Meeting their Report and Abstract of Accounts for the year 1861-62.

It will be seen by the accompanying Table, which shews the present state of the Institution with respect to Members, and the casualties affecting increase and decrease, that during the past year there have been added to the Institution, after allowance made for deaths, withdrawals, and promotions, 56 Members.

RANK.	£	s.	d.	April, 1861.	Since joined.	Promoted or withdrawn.	Deceased.	April, 1862.
EFFECTIVE LIST.								
General and Regimental Field Officers, paying annually	1	5	0	139	+ 11	0	— 5	145
Captains	0	16	0	327	+ 26	— 5	— 7	341
Lieutenants	0	10	0	392	+ 60	— 20	— 9	423
Quarter-Masters	0	10	0	5	0	0	0	5
Riding-Masters	0	10	0	2	0	0	0	2
Surgeons-Major	1	5	0	3	+ 1	— 1	0	3
Surgeons	0	16	0	7	0	— 1	0	6
Assistant-Surgeons	0	10	0	18	+ 6	— 2	0	22
Veterinary Surgeons	0	10	0	2	0	0	0	2
RETIRED LIST.								
General and Regimental Field Officers	1	5	0	14	+ 2	0	0	16
do. do.	0	16	0	1	+ 1	0	0	2
do. do.	0	10	0	6	+ 2	0	0	8
do. do.	0	7	6	8	0	0	0	8
Captains	5	0	0	1	0	0	0	1
do.	0	16	0	11	0	0	0	11
do.	0	10	0	8	0	— 4	0	4
do.	0	5	0	6	+ 2	0	0	8
Lieutenants	0	10	0	1	0	— 1	0	0
				951	+111	— 34	— 21	1007
Honorary Members	0	10	6	35	0	— 4	— 1	30

The Committee cannot pass without observation the loss of so many Members during the year by death. The number amounts to 21, a far

higher rate than the average of past years. They refrain from singling out any names for special regret, where doubtless all are truly mourned by many attached comrades and friends.

It is with much satisfaction that the Committee record the addition to the list of Members of many of the Officers of the late India Artillery, chiefly those serving in this country, but some also among those serving in India. It may be well to remind the General Meeting that, shortly after the amalgamation between the two services was completed, measures were adopted for sending to every Officer of the late Bengal, Madras, and Bombay Artilleries a general invitation to become a Member of the Institution. Before issuing these invitations, certain preliminary arrangements were necessary; these have been the subject of correspondence, through the D.-A.-General, between the Committee and H. R. Highness the General Commanding-in-Chief, and Her Majesty's India Government. When the correspondence is closed (it is hoped satisfactorily) no time will be lost in forwarding to every Artillery Officer on the late India Establishment, a short history of the origin, object, and present features of the Institution, together with a copy of the Rules, terms of subscription, &c.; and the Committee are sanguine enough to hope that out of that distinguished body of Officers now united with us in one Regiment, a large proportion will be numbered among the future supporters of the Institution.

Every year marks a steady increase in the number of Members, a fact which, while it brings with it a wider field of usefulness, should operate as a stimulus to all concerned to endeavour to make the benefits of the Institution commensurate with its increasing opportunities.

A growing desire is manifested for fuller information on all matters relating to the Profession, and recent questions of great moment in which, as a Regiment, the members of this Institution are intimately concerned, render it imperative upon the Committee to spare no pains to make the Professional Papers issuing from the Institution worthy of the Association from which they proceed, and valuable to those who receive them.

In order that this may be done more effectually in the future than hitherto, it is hoped that hinderances to the obtaining information, arising from any excess of official secrecy, may be removed; and that the Committee may have cause thankfully to acknowledge the spontaneous grant by Her Majesty's Government of information on many points, while it is yet fresh, concerning which Officers of the Royal Artillery might be safely enlightened with advantage to the Public Service.*

At the same time while legitimately looking for help and encouragement to the Government whom they serve—which help and encouragement this Institution has already in many ways liberally received—it is incumbent on the better informed Members of the Corps not to be behindhand in imparting (through the medium of the printed "Proceedings"), much of that knowledge for which as a Regiment they are justly famed, for the benefit of their brother Officers.

The Committee therefore leave this subject in the confident expectation that their appeal for written contributions from the Corps at large will not be disregarded.

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* The above remarks have reference specially to accounts of Experiments, &c.

In submitting the Annual Statement of Accounts for the past year, the Committee observe with satisfaction that not only has the income for the

General Abstract of the Income and Expenditure of the Royal Artillery Institution,

From 1st April, 1861, to 31st March, 1862.

Dr.

	£	s.	d.
Printing and Publication. Wages	196	0	0
Printing and Publication. Paper	380	3	0
Printing and Publication. Type and Materials	214	18	1
Printing and Publication. Lithography	43	7	3
Chemistry	102	2	0
Photography	54	19	8
Drawing	40	1	0
Prints and Engravings	36	10	0
Library, Books, &c.	72	8	9
Museum	22	9	0
Instruments	32	6	0
Carpenter, Materials	57	9	0½
do. Wages	17	10	6
Insurance	10	0	0
Furniture and Repairs	43	10	3
Subscriptions to Societies	6	6	0
do disallowed	1	5	0
Stationery	25	15	2
Postage and Parcels	27	12	0
Wages, Clerks and Orderlies	80	16	3
Incidental	35	3	4½
Balance Creditor Consols Stock	700	0	0
Balance Creditor Cash	2	2	10½
	£2202	15	2½

Cr.

	£	s.	d.
Balance Creditor, 1st April, 1861 ... Consols Stock	700	0	0
Balance Creditor, 1st April, 1861 ... Cash	8	17	3
Dividend on Consols	20	4	4
Subscriptions	779	1	0
General Printing	534	9	0
Chemistry	19	7	9
Photography	37	16	1½
Drawing	23	3	9
Taxidermy	0	12	0
Library, Books, &c.	11	6	3
Carpenter, Wood, &c.	10	4	8
Stationery	39	8	4
Postage and Parcels	7	4	7
Due Messrs. Cox and Co.	11	0	2
	£2202	15	2½

May 20, 1862.

(Signed) E. J. BRUCE, Capt. R.A.,
Secretary and Treasurer, R. A. I.

year been sufficient to meet the current expenses, but that the amount of former bills owing at the close of the year 1860-61,* has been paid off from the same source.

The following brief abstract will shew clearly the position as regards income and expenditure for the past year:—

Dr.	£	s.	d.	*Cr.*	£	s.	d.
Outlay for the past year (including payment of £464 2s. 8½d., bills due for former periods)	1500	12	4	Cash in hand 1st April, 1861	8	17	3
Outstanding debts of R.A.I. (including balance of £11 0s. 2d. due to Messrs Cox and Co.)	102	9	2	Income for the past year......	1482	17	9½
Balance, Cr.	81	14	6½	Amount due by Members to R. A. I.	66	1	0
				Value in hand, printing paper, and stock kept for sale	127	0	0
	£1684	16	0½		£1684	16	0½

There is farther a sum due to the Institution from Her Majesty's Government, for the sale of "Hand Books," amounting to £253.† Besides this, the value of the "Hand Books" yet unsold, about 1000, will in course of time realize a similar amount.

On the whole then, as was anticipated in the Annual Report of last year, the produce of the "Hand Book," together with a strict economy in matters of expenditure, have restored the funds of the Institution to their original flourishing condition.

The state of the General Fund is as follows:—

	£	s.	d.
Consols and Cash	702	2	10½
Balance Cr. on the last year's Abstract (taking into account outstanding debts and credits)	81	14	6½
	£783	17	5

Printing and Publication.—The following is a list of the "Proceedings" and other papers printed during the year:—

Report of a Professional visit to the Continent by Artillery Officers.

Obituary Notice of the late Lieut.-Col. W. M. Leake, R.A., extracted from the President's address at Anniversary Meeting of the Geographical Society, May 1860.

The Parallax of the Sextant, and its influence upon observed angles. By Captain Drayson, R.A.

Report of Ordnance Select Committee, Nos. 1178, 1263, Oct. 17, 1860. Iron Embrasures of special construction at Shoeburyness. Communicated by direction of the Secretary of State for War.

On the determination of distances in the field. By Lieut.-Col. H. Clerk, R.A., F.R.S.

Notes on the Early History of Artillery. By the late Col. Cleaveland, R.A.

Desultory Notes at Takoo. By an Officer of the Siege Train.

The Royal Artillery at Canton. By an Officer of the Royal Artillery.

Despatch of Captain Mercer, R.A., commanding the Royal Artillery in New

* £464 2s. 8½d. † Since received.

Zealand, during operations from 13th to 19th March, 1861. Communicated by the Deputy-Adjutant-General, R.A.

Report of Ordnance Select Committee, No. 1404, January, 26, 1861. Breaching experiment with smooth-bored guns against Martello Tower No. 49, near Bexhill, Sussex. Communicated by direction of the Secretary of State for War.

Annual Report and Abstract of Proceedings of a General Meeting of the Royal Artillery Institution, held on Monday, May 13, 1861. Col. Dick, R.A. in the Chair.

Report of Ordnance Select Committee, No. 1484, March 7, 1861. Mantlets for the protection of Artillerymen from an enemy's riflemen. Communicated by direction of the Secretary of State for War.

Abstract shewing the Mean Initial Velocities of various Service and Experimental Projectiles, determined by Captain Andrew Noble, R.A., under direction of the Ordnance Select Committee, by means of Navez electro-ballistic apparatus.

Navez electro-ballistic apparatus. Table shewing the relations between the Arcs passed through and the corresponding Durations for $t=0''\cdot3337$. By Lieut. W. H. Noble, R.A.

"On the Influence of Atmospheric Pressure upon some of the Phenomena of Combustion." By Dr. Edward Frankland, F.R.S., extracted from Proceedings, Royal Society, Vol. XI. p. 137.

The production of the third edition of the "Hand Book for Field Service" already alluded to, has occupied a considerable portion of the printers' time, and thus in some degree has limited the amount of other matter. But now that this important work is completed, the Committee hope (through the assistance they have solicited in the commencement of the Report), to keep up a constant supply of useful "Papers" on subjects of professional interest to the Regiment.

In consequence of the amalgamation of the Artillery services, the Distribution List of the several Brigades and Batteries with their respective Stations, together with the Departmental Divisions, now forms a sheet of no mean pretension, giving in a convenient form, and in small compass, information not readily to be obtained elsewhere. The Seniority List, though enlarging with a slower growth, is yet increasing from year to year.

These are now sent monthly, without charge, to every Battery, as well as to Brigades, and Departments; and are obtainable by members, price 3*s.* per annum, including postage.*

Library.—Under this head will be found a list of books purchased and presented; also of plans, maps, &c.

Among the latter will be noticed the usually large proportion liberally presented by the Topographical Branch of the War Department.

At the recommendation of H.R.H. the General Commanding-in-Chief, the Secretary of State for War was pleased to grant that the photographs of guns, matériel, and in some cases views taken after experiments, &c., executed by the Photographic Department of the War Office, might be purchased by the Officers of the Regiment, on application to the Secretary of the Institution.

These photographs are mounted on card, price 1*s.* or 1*s.* 6*d.* each, according to size. Lists of the new ones, as they arrive, are published from time to time, for the information of Members.

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* **Foreign Postage charged additional.**

There are also lithographs, drawn to scale, of guns, carriages, &c. &c., executed at the Royal Carriage Department, Royal Arsenal, which are likewise sold at the Institution, price 6*d.* each sheet.

Presentations of Books, Plans, Maps, &c.

View of the Dockyard Buildings, Sebastopol	1	Capt. T. L. Dames, R.A.
Stereoscopic views of the Temple of Apollo, at Bassæ	8	Lt.-Col. J. D. Shakespear, R.A.
Review of the Crimean War	1	Col. T. M. Adye, R.A. C.B.
Geometrical Projection of $\frac{2}{3}$ of the sphere ...	1	Colonel Sir Henry James, &c. &c. R.E., Topographical Depôt, War Department.
Annual Reports of the Smithsonian Institution, Washington, 1859-1860	2	Smithsonian Institution, Washington, U.S.
Smithsonian Contribution to Knowledge	1	
Exploration for a Railway Route from the Mississippi River to the Pacific Ocean, Vol. XII.	2	
Geological Reconnoissance of Southern and Middle Counties of Arkansas	1	
Pamphlets on the construction of Iron-clad Ships of War	2	Col. J. M. Adye, R.A. C.B.
Manual of Artillery Exercises, 1861	1	The Dept. Adjut.-General, R.A.
Abstract shewing Mean Initial Velocities of various service and experimental projectiles	1	Ordnance Select Committee.
Report on an Hospital at Tein-Tsin for Chinese	1	Brig.-Gen. C. W. D. Staveley.
Ancient Maps, dating from 1708	7	Riding-Master Donald, R.A.
British Carboniferous Brachiopoda	1	Palæontographical Society.
Royal United Service Journals, Nos. 19 and 20	1	Council, Royal U. S. Institution.
Notes on Matériel as at present issued for smooth-bored ordnance	1	Captain G. H. J. A. Fraser, R.A.
Journal of Russian Artillery	1	Count N. de Novitzki.
Description du Manege Moderne, (Ancient Work) ...	1	Captain L. G. Paget, R.H.A.
Map of Montenegro	2	Topographical Depôt, War Department.
Sketches of the neighbourhood of Fort Monroe, Norfolk Harbour, and of Pensacola Bay, Fort Pickens.	4	
Plans of Massena's Retreat	6	
Lithographs of Guns, Carriages, Wagons, &c.	17	Royal Carriage Department.
Photographs of do do	91	Photographic Depôt, War Department.
Photographic views of Corfu	6	Lt.-Col. J. D. Shakespeare, R.A.

Books Purchased.

Encyclopædia Britannica, Vols XX. and XXI.	2
Birds of Asia (Gould's), Vol. XIII.	1
Penley's Art of Drawing in Water Colours	1
Bowman's Chemistry	1
Common Scenes in the Heavens. By Capt. Drayson, R.A.	1
Goodeve's Mechanics	1
Drayson's Military Surveying	1
Aide Mémoire des Officiers d'Artillerie	1
Colenso's Algebra	1

Publications of Learned Societies. Periodically.

Comptés Rendus.	Journal für die reine Mathematik.
Le Spectateur Militaire.	Journal des Armes Spéciales.
Journal de Mathématiques.	Journal of Royal Society, No. 47.
Journal des Sciences Militaires.	Journal of the Society of Arts.

Museum.—During the past year several additions have been made to the Ornithological part of the Museum, the chief of which is a very valuable collection of American birds, presented by the Smithsonian Institution, Washington; among these are some rare specimens, also a small but interesting collection of humming birds and others from Berbice, presented by Lieut.-Colonel Wragge; a small parrot (*nanodes undulatus*), and some reptiles, and insects, from Australia, by Lieutenant Hallet. To the case of British birds, a few specimens have been added; and as the completion of this part of the collection depends specially on the Members themselves, it is hoped that those who are able to assist will do so, by sending specimens either in the fresh state or in skins. A list of the birds and eggs wanted has already been published in one of the numbers of the "Occasional Papers."*

Members stationed at any of the West India islands would be conferring a great boon by sending specimens of humming birds, and also their nests and eggs, with any notes of their habits that they might think to be of interest.

The case of shells is in course of arrangement. Any donations to this division of the Museum would be of value, particularly in the families of *Cones, Volutes, Cypræa,* and *Murices*. British shells are also in request. Members stationed on the coast might pass an idle hour, perhaps with amusement and profit too, in collecting them, being led on from merely collecting to study and take an intelligent interest in the modes of life of the curious little people that inhabit these many shaped and often richly coloured dwellings.

As regards insects, the Museum is still very deficient, and considering that the Institution possesses Members in all parts of the world, it is felt that this collection ought to be inferior to none. The Committee hope this inferiority will not be suffered to remain.

Presentations to the Museum.

Book containing 270 specimens of Jersey Sea Weed, admirably prepared, and scientifically arranged	1	Captain P. Sorel, Royal Jersey Militia Artillery.
Birds from America	92	Smithsonian Institution.
Autograph Letter of Lord Nelson's	1	Captain Freeling, R.A.
Egyptian Mummy (Glass Case presented by Council R. U. S. I.)	1	Transferred from the R. U. S. Institution, by Gen. Wood.
Specimen of Iron Piping formed by the percolation of water, with iron in solution through sand	2	Lieutenant W. H. Noble, R.A.
Shot and Shell taken from Chinese Guns since their arrival in the Royal Arsenal	3	Captain J. Lyons, R.A.
Model of a Canadian Canoe		Major-General Belson, R.A.
Old Naval Cat-o'-nine-tails	1	
Fossils, &c. from Egypt	7	Captain O. Carr, R.A.

* Vol. II. pp. 57—61.

Indian Sword	1	Lt.-Gen. Sir W. M. Colebrooke, C.B., K.H. ....
do do	1	Lieutenant J. M. Maunsell, R.A.
Chinese Work on Fortification	1	Asst.-Surgeon Taylor, R.A.
Indian Vegetable Wax Candles	4	Col. J. H. Lefroy, R.A. F.R.S.
Chinese Plan of Tein-Tsin River..............	1	Captain T. A. J. Harrison, R.A.
do do of Upper North Fort (Taku)...	1	
do Official Envelope	1	
do Fuze (incomplete)	1	
Geological Specimens		Colonel Bainbrigge, R.E.
Humming Birds from Berbice....................		Lieut.-Colonel Wragge.
Bottles of Reptiles	4	Lieutenant Hallett, R.A.
do	2	Lieutenant Thurlow, R.A.
Suit of Chinese Armour	1	Asst.-Surgeon Finnemore, R.A.
Old Pattern R.A. Cross Belts..................	2	Col. F. Eardley-Wilmot, R.A.

American Birds presented by the Smithsonian Institution, Washington.

Catalogue No.	Species.	Sex.*	Locality.	Original No.	Common Name.	Date.
337	Geococcyx californiaus	m	... ...	4054	Chaparral cock	......
338	Coccygus americanus........	f	Cape May, New Jersey	11632	Yellow-billed cuckoo	July 42
339	Picus harrisii	m	Bitter Root Valley ...	17524	Harris' woodpecker	......
340	do	f	Mouth of Big Sioux ...	4638	do	May 3
341	Picus pubescens	f	Salt Creek	7049	Downy woodpecker...........	May 29, 57
342	do	m	St Louis	7048	do	May 8, 57
343	Picus scalaris	...	Coralado River, California	4574	... ...	......
344	Centurus Carolinus...........	m	St Louis	7050	Red-bellied woodpecker	May 13, 57
345	Melanerpes erythrocephalus	...	Wagon Road to Bridger's Pass	5613	Red-headed woodpecker......	......
346	do do	y	Labout River...........	13249	do do	Aug. 8, 58
347	Melanerpes formicivorus ...	...	Umpqua Valley.........	4464	Californian woodpecker	1855
348	Colaptes mexicanus	...	Fort Sletiacoon, West Texas	6109	Red-shafted flicker	March 56
349	Chordeiles popetue	...	Washington	7590	Night-hawk.....................	......
350	Milvulus forficatus	f	Fort Cobb	19074	Scissor-tail	May 24, 60
351	Tyrannus verticalis...........	f	... ...	5257	Arkansas flycatcher	June 2
352	do	...	... ...	13776	do do	......
353	Myiarchus crinitus	...	St Louis	6970	Great crested flycatcher......	May 8, 57
354	Myiarchus mexicanus.........	f	California	3720	Ash-throated flycatcher	......
355	Sayornis fuscus	m	... ...	4897	Pewee	May 7, 56
356	do	...	Washington	7586	do	......
357	Empidonax minimus	m	... ...	4700	Least flycatcher	May 15
358	Turdus migratorius...........	...	Rockport, Ohio	7477	Robin	......
359	Sialia sialis	...	... ...	7404	Blue bird	......
360	do	m	On Loup Fork, Platte	8880	do	......
361	Sialia mexicana	f	... ...	7632	Western blue bird	......
362	Regulus satrapa	m	... ...	15939	Golden-crested wren	Nov. 5, 59
363	Hydrobata mexicana	f	Deer Creek	19195	Water ouzel	Jan. 5, 60
364	Mniotilta varia	m	... ...	11614	Black and white creeper ...	......
365	Parula Americana	...	Rockport, Ohio	7488	Blue yellow-backed warbler	May 52
366	Geothlypis trichas	m	Sioux City	13189	Maryland yellow throat......	......
367	Geothlypis macgillivrayi ...	...	... ...	7909	Macgillivray's warbler	July 28
368	Icteria viridis	m	... ...	11972	Yellow-breasted chat	May 10, 59
369	Seiurus aurocapillus	m	Pensylvania	10537	Golden-crowned thrush	May 41
370	Dendroica virens..............	...	Cleveland, Ohio.........	7500	Black-throated green warbler	......
371	Dendroica canadensis.........	...	Rockport, Ohio	7304	Black-throated blue warbler	......
372	do do	f	Cleveland, Ohio.........	7306	do do	......
373	Dendroica coronata...........	...	Rockport, Ohio	7441	Yellow rump	......
374	Dendroica audubonii	...	... ...	13291	Audubon's warbler	......

* *m* denotes male, *f* female, *y* young.

Catalogue No.	Species.	Sex.	Locality.	Original No.	Common Name.	Date.
375	Dendroica striata	...	... ...	7062	Black poll warbler	......
376	Dendroica maculosa	...	... ...	7339	Black and yellow warbler ...	......
377	Dendroica palmarum	...	... ...	7355	Yellow red pole	......
378	Pyranga aestiva	*m*	... ...	8294	Summer red bird	May 25, 57
379	do	*f*	Fort Cobb	19483	do	......
380	Pyranga ludoviciana	*m*	... ...	18462	Louisiana tanager	May 25, 59
381	Hirundo lunifrons	*m*	... ...	18324	Cliff swallow	......
382	do	*m*	Fort Bridger, Utah ...	11018	do	June 20, 58
383	Hirundo bicolor	*m*	do ...	11029	White-bellied swallow	May 18, 58
384	Hirundo thalassina	*m*	do ...	11040	Violet green swallow	May 17, 58
385	Ampelis garrulus	*m*	Racine, Wisconsin ...	5822	Wax wing	Nov. 10, 56
386	Phainopepla nitens	*m*	... ...	8278	... ...	......
387	Vireo olivaceus	...	... ...	7324	Red-eyed flycatcher	......
388	Mimus polyglottus	...	... ...	8163	Mocking bird	1852
389	Cistothorus palustris	...	Mouth of Big Sioux...	4744	Long-billed marsh wren ...	May 6, 56
390	Troglodytes aedon	...	Cape Florida	8642	House wren	Oct. 30, 57
391	Troglodytes parkmanni	...	... ...	13781	Parkman's wren	......
392	Troglodytes hyemalis	*f*	... ...	20919	Winter wren	Dec. 21, 59
393	Sitta carolinensis	...	Washington, D. C. ...	7595	White-bellied nuthatch	......
394	Sitta aculeata	...	Chain River	19229	Slender-billed nuthatch	Oct. 29,
395	Sitta canadensis	...	... ...	11609	Red-bellied nuthatch	......
396	Polioptila caerulea	*f*	... ...	10215	Blue grey flycatcher	April 20,
397	Lophophanes bicolor	...	Washington, D. C. ...	7579	Tufted titmouse	......
398	Parus septentrionalis	...	Black Hill, Upper Missouri	8828	Long-tailed chickadee	Sept. 15,
399	Parus rufescens	...	... ...	6790	Chesnut-backed tit	......
400	Carpodacus purpureus	*f*	Washington, D. C. ...	10141	Purple finch	......
401	Chrysomitris tristis	...	... ...	6394	Yellow bird	......
402	Curvirostra americana	...	... ...	7298	Red crossbill	......
403	Chondestes grammaca	...	... ...	19084	Lark finch	June 8, 60
404	Zonotrichia leucophrys	*m*	Fort Bridger, Utah ...	11138	White-crowned sparrow ...	May 22, 58
405	Zonotrichia gambelii	...	... ...	18040	... ...	Aug. 12, 60
406	Zonotrichia albicollis	*m*	Washington, D. C. ...	10144	White-throated sparrow ...	......
407	Junco oregonus	*f*	Fort Bridger, Utah ...	11177	Oregon snow bird	April 12, 58
408	Spizella pusilla	...	... ...	19092	Field sparrow	May 24, 60
409	Melospiza melodia	*m*	... ...	11676	Song sparrow	......
410	Passerella iliaca	*m*	Washington, D. C. ...	10134	Fox-coloured sparrow	......
411	Calamospiza bicolor	*f*	... ...	6369	Lark bunting	......
412	Guiraca melanocephala	*m*	Powder River	13209	Black-headed grosbeak	......
413	Cyanospiza amoena	*m*	Wind River	19245	Lazuli finch	May 25, 60
414	Cyanospiza cyanea	*m*	... ...	10527	Indigo bird	July 46
415	Cardinalis virginianus	*m*	Calacasieu Pass	4278	Red bird	1854
416	do do	*f*	St Louis	7031	do	May 8, 57
417	Pipilo chlorurus	...	Utah	13350	Blanding's finch	
418	Dolichonyx oryzivorus	*m*	Fort Pierre	5360	Boblink	June 25, 56
419	do do	...	... ...	10531	do	May 49
420	Sturnella neglecta	...	Presido, near St Francisco	8624	Western lark	May 6, 53
421	Icterus spurius	*m*	... ...	5348	Orchard oriole	May 28, 56
422	Icterus bullockii	*f*	Petaluma, Sonona, California	5525	Bullock's oriole	May 11, 56
423	Scolecophagus cyanocephalus	*m*	Fort Bridger, Utah ...	11925	Brewer's blackbird	June 19, 58
424	Quiscalus versicolor	*m*	... ...	4760	Crow blackbird	April 25,
425	Picicorvus columbianus	*m*	Hell Gate	18364	Clark's crow	......
426	Cyanura cristata	*f*	St Louis	7000	Blue jay	May 8, 57
427	Cyanocitta californica	...	Camp 149, California	8462	California jay	Mar. 16, 54

Birds Presented by Lieut.-Colonel Wragge.

No.	Species.	Sex.	Locality.	No.	Species.	Sex.	Locality.
428	Ampelis pompadora	*m*	Berbice	438	Trochilus prasina	*m*	Berbice
429	" cotinga	*m*	"	439	" moschitus	*m*	"
430	Oriolus chrysocephalus	*m*	"	440	" "	*f*	"
431	Certhia cœrulea	*m*	"	441	" mellivorus	*m*	"
432	" "	*f*	"	442	" "	*m*	"
433	Trochilus pella..................	*m*	"	443	" cyanogenys........	*m*	"
434	" "	*y*	"	444	" "	*m*	"
435	" mango	*m*	"	445	" furcatus	*m*	"
436	" "	*y*	"	446	" "	*m*	"
437	" gramineus	*m*	"	447	" "	*m*	"

Languages.—The Classes for the study of the French and German languages have continued throughout the year.

Surveying and Practical Astronomy.—Captain Drayson has attended regularly to give instruction to all Officers desirous of availing themselves of his services.

Photography.—The facilities afforded, by the excellent apparatus and rooms specially constructed, for the pursuit of this art, within doors, as well as the Photographic Tent for Landscape Photography, will, it is hoped, lead to a more prevalent use of these means than has been the case hitherto. It is the desire of the Committee to encourage, as far as they are able, the acquisition by Artillery Officers of an art so interesting in itself, and applicable to so many useful ends.

The services of an instructor are now engaged, pending only the announcement of a sufficient number of names to form a Class.*

Chemistry.—The admirable Laboratory, well stocked with every appliance for the pursuit of this most interesting science should induce many Members to avail themselves of the opportunities within their reach, for following up the knowledge they gained at the Royal Military Academy. The Class meets for instruction once a week, but every Member of the Class is free to pursue his studies in the interval.

Taxidermy.—Mr Whitely, the curator of the Museum, is always at hand to instruct in the method of preparing and setting-up birds, &c; and it is much to be desired that many of the younger Officers, whose love of sport is doubtless keen, should acquire by a few simple lessons, before they go abroad, the power to preserve the best specimens they may obtain in their shooting excursions. The insight that Mr Whitely could also impart in many of the branches of Natural History would be of great advantage to those who may yet be quartered in Foreign Stations abounding with opportunities of gratifying a taste for this study.

Drawing.—A numerously attended Drawing Class has been formed, and well maintained, under Mr Aaron Penley.

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* Since this Report was written a numerous Class has been formed, and a good beginning made.

Lectures.—Besides the most interesting and instructive Lectures delivered in the Theatre of the Building to the Gentlemen Cadets, to which all Members have access, embracing the following subjects: Applied Chemistry, Natural Philosophy, Practical Mechanics, and Geology and Mineralogy, the Committee have provided other series of Lectures such as the Lectures by Mr Bloxam "On the Chemistry of Water," and those by Mr Waterhouse Hawkins "On the ancient and recent Vertebrate Animals, &c."

The Committee have further to thank Major Miller, R.A. VC, Topographical Staff, for two most interesting Lectures "On the Italian Campaign of '59."*

Evening Meetings.—The "Evening Meetings," for some time discontinued, have been resumed with every promise of continuance. They are at present held once a fortnight, on Monday at 8.30 p.m., in the Theatre of the Building; and some interesting discussions have taken place.

At these Meetings "Papers" sent by Members at a distance are read; and from these a selection is made by the Committee of such as shall be printed and circulated in the "Proceedings."

Models.—It is matter for regret that the Institution possesses scarcely any Models, whereas nothing can be more instructive or more in harmony with the character of this Institution than a well-stocked Model Room.

By the liberality of H.M. Government, at the instance of the Director of Ordnance, a grant has been made of a new assortment of Royal Laboratory specimens at present in use in the service, to replace the former grant now much impaired and partly obsolete. This important addition, will it is hoped, soon be received.

Ancient Arms and Uniforms.—Donations to this Department are made from time to time; and it would be interesting to possess complete suits of the Officers' uniforms at least, from the formation of the Regiment to the present day. A few curious contributions have been occasionally made in this direction. It is possible some of the senior Officers of the Corps may be enabled to add something to this division.

Photographic Likenesses and Views of Foreign Stations.—The Committee remind the Regiment at large that a collection has been for some time in progress of Photographic Likenesses of all its Members; and they earnestly request all Officers who have not yet responded to the circular issued on the subject to contribute their likenesses, and thus complete what will prove, in course of time, one of the most interesting Records of the Regiment.

Likewise Photographic Views or Water Colour Drawings, of Home and Foreign Stations to which Artillery Officers are liable to be sent, are in great request; and the Committee feel it due to Lieut.-Colonel J. D. Shakespeare, R.A., to make special acknowledgement of six admirable Photographic Views, taken by himself, in the island of Corfu, and contributed by him towards this collection.

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* Copies of Major Miller's work "On the Italian Campaign of '59," with plans, may be had at the R.A. Institution.

Proposed by Colonel Wilford, R.A., seconded by Major Young, R.A., and carried unanimously,—

"That the thanks of the General Meeting be expressed to Captain Noble for the time and labour devoted by him to the revision of the third edition of the 'Hand Book for Field Service,' to which careful preparation is mainly due the success of the present edition."

It was further Resolved,—

"That the thanks of the General Meeting be conveyed to Captain Blakiston, R.A., for the renewed expression of his interest in the Natural History Museum by his presentation to the Institution of a highly interesting collection of Birds of China, obtained by him during his late expedition in that country."

A vote of thanks was also passed to the Committee, for their unremitting attention to the interests of the Institution during the past year.

In consequence of the frequent changes in the Garrison, nearly the whole of the Members of the Committee have been elected so recently as to render it expedient, in the view of the General Meeting, to limit the application of Rule IV. in the present case, to the retirement of one Member of Committee only, viz. Lieutenant Crawford, R.A.

Resolved,—

"That Lieut.-Colonel Gibbon, R.A. C.B., be requested to serve on the Committee, to fill a vacancy already existing; also that Lieut. Edmeades, R.A. be requested to serve in lieu of Lieutenant Crawford who retires in accordance with a modified application of Rule IV."

The Committee for the ensuing year will therefore stand thus:—

PATRON AND PRESIDENT:

General H.R.H. The Duke of Cambridge, K.G.

VICE-PRESIDENTS:

The Commandant.
The Deputy-Adjutant-General.

MEMBERS OF THE COMMITTEE:

The Assistant-Adjutant-General.
The Secretary Ordnance Select Committee.
The Brigade Major.

Lt.-Col. J. H. Smyth, C.B.
Lt.-Col. H. Clerk.
Lt.-Col. J. B. Gibbon, C.B.
Lt.-Col. M. Clifford.
Surg.-Major H. Briscoe, M.D.
Major C. F. Young.
Major C. H. Owen.
Major W. G. Andrews.

Captain T. L. Dames.
Captain H. A. Doyne.
Captain J. Lyons.
Captain V. D. Majendie.
Lieut. C. F. Roberts.
Lieut. H. Edmeades.
Lieut. W. G. Stirling.
Captain E. J. Bruce,
Secy. and Treasurer.

(Signed) SIR R. J. DACRES, Major-General,
Vice-President, in the Chair.

May 20, 1862.

THE QUESTION OF THE DAY,

OR

"IRON-PLATES" *VERSUS* "GUNS."

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ASSOCIATE MEMBER, ORDNANCE SELECT COMMITTEE.

1. The actual "work done" at the moment of impact, by two projectiles of different weights and animated with different velocities may be taken as comparatively proportional to the *vis viva* of each.

This is not, strictly speaking, quite correct, as some force is expended in altering the shape of the different shot when they strike.

Upon a projectile striking a rigid and immovable object, like an iron target, a certain alteration of figure is experienced by the shot; but the difference between the forces required to produce this effect in different shot is so inconsiderable that it may practically be neglected, and the "work done" may be stated, as above, to vary as Wv^2, W being the weight of the shot, and v its velocity *at the moment of impact.*

The work done, at 200 yds. distance, by the 110-pr. Armstrong rifled gun, with 14 lbs. charge, where $W=111$ lbs. and $v=1178$ ft., and the 68-pr. smooth-bore gun, with 16 lbs. charge, where $W=66$ lbs. and $v=1422$ ft., is in favour of the former gun in the proportion of 11·5 to 10, nearly; but we find that the penetration is in favour of the smooth-bore 68-pr. Again, at the same distance, the 110-pr. firing a bolt of 200 lbs. with a charge of 10 lbs., where $W=200$ lbs. and $v=780$ ft., in comparison with the 68-pr. as before, will be as 10 to 11, nearly, the 68-pr. thus, having a slight advantage; yet the penetration of the 68-pr. is far greater, that of the 200 lbs. bolt being almost nothing.

2. How comes it then, that although the "work done" by each shot varies so little, the penetrations shew such a marked difference? I think that the following explanations will throw a light on the subject:—

The actual "work done" by each shot is, as we have seen, nearly the same; but *one* does its work *in much less time than the other.* This explains the whole matter.

The 200 lbs. bolt, *with a low velocity,* strikes a heavy blow on a spot in the target, but it takes a certain length of time to accomplish that blow; so that, during this interval, all the surrounding particles of iron have ample time to sustain the point struck; the force of the blow is thus spread over a large surface of the target, and the cohesion of the particles is undisturbed,

as each particle is enabled to contribute the force of its attraction towards uniting the whole.

The 68-pr. on the contrary, strikes the target with a high velocity, and the surrounding particles have not time to sustain one another, before the work is accomplished, so as to support the point struck; the consequence is that the penetration is greater at the point struck, although the actual amount of "work done" may be the same.

3. Lest this language should appear too figurative, I will express it in other words, thus:—

Let us suppose the matter of which any body is composed, to be comprised of an indefinite number of atoms or particles united together by a certain force.

Call one of these atoms A and the contiguous atoms B and C, these last have also contiguous atoms D and E and so on. Suppose the atom A receives a blow, it instantly endeavours to transmit some of the effects of this blow to B and C, which again in their turn transmit to E and D, thus a sort of wave of motion takes place between the particles, and each atom bears some of the effect of the blow. But a certain time must have transpired before the wave communicates its effect to E and D. If there is sufficient time to enable, B, C, D, E to take up some of the effect, A will, in a corresponding degree, be relieved; but if there is not sufficient time A will have a greater force to contend with than it is able to resist, consequently it must yield to that force and alter its position with regard to the contiguous particles,

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4. I think it ought to be allowed that the chief object we have in view is the penetration of the ship's armour; it will have a moral effect on the crew as well as a physical effect on the vessel, for if once an armour coated ship is penetrated her prestige is gone and she is no longer invulnerable. It is said "the heavy shot has a great *smashing* effect!" But practically, up to this time, we know it has not been so; the penetrating effect of the 200 lbs. bolts on the *Warrior* target being quite insignificant, and from the best and most authenticated accounts we learn that the late naval battle in America was fought with these heavy shot, at low velocities, and that the result was almost *nil*.

The champions of the "heavy weights" say that the heavy shot at low velocities will shake the plate off, and break all the bolts; and no doubt such results would be most effective—*if they took place*. However up to the present date these results have not taken place; the plates in the most obstinate manner refuse to be shaken off, even when fired at directly.—What then will be the effect if they are fired at obliquely?

Observe the effects produced upon the *Warrior* target.

The mean penetration of the 68-pr. was 2·46.in., that of the 110-pr. Armstrong with a shot of 111 lbs. and 14 lbs. charge, 1·6-in., while the penetration of the 200 lbs. bolt was almost inappreciable. What was the penetration of the "shunt" gun with a shot of 140 lbs. and 20 lbs. of powder? not much more than the 68-pr., although the "work done" was

nearly as 17 to 10. But the time of doing this work was longer in one case than the other.

If I could see any practical advantage in using a heavy shot with a low velocity, *against iron,* I would at once yield to its superior merits; but on the contrary, this system is more expensive, more difficult to manage, and less effective than a system of lighter shot and heavier charge.

It is quite possible that a gun might be made to throw such a heavy shot that it would be irresistible. But it is quite as possible that a smaller gun, throwing a smaller shot, with greater velocity might be just as powerful, and decidedly easier to work and cheaper to use. The problem is this,—Required, to find a means of destroying your enemy in the shortest time, in the easiest manner, and at the least possible expense.

5. The question now becomes one of guns. After the late experiments on the *Warrior* target at Shoeburyness, no one will be bold enough to deny that the true way to penetrate a ship's armour is by using heavy shot animated with a high velocity, or, in other words, fired with a large charge of powder. In the recent experiments the "work done" by Sir W. Armstrong's large smooth-bore gun, throwing a spherical shot of 150 lbs. with a charge of 50 lbs. was as 3 to 1 in comparison with the 68-pr.; it therefore penetrated the plates with the greatest ease, although the shot itself was broken into small pieces by the concussion. This effect was due, not to its being a smooth-bore, but to the projectile's great velocity.

A very unscientific mistake is made by those who imagine that for penetration through iron plates it is absolutely necessary to have smooth-bored ordnance.

We know what a prejudice for a long time existed against rifled small arms; and how "Old Brown Bess" was hugged to the last.

We know what a hard fight every improvement has to endure before a change is effected. It has to conquer habit, prejudice, professional jealousy, and a host of other enemies, but in the end it triumphs. Thirty years ago we thought a "four-in-hand" and twelve miles an hour all that could be desired for speed; the old seventy-four gun ship was looked upon as the model of naval architecture; the ordnance of the period was on the same scale. Less than half a century elapses, and everything is changed; the genius of man ever striving onward overcomes the obstacles in its path. The mighty arm of machinery is called into play, and an iron age commences.

Who would compare the railway engine of the present day with the coach of yesterday? How would the old "74" compete with the modern line of battle ship, or the artillery of the past with the heavy ordnance of the present? This latter in its turn will be superseded and the rifle will take its place.

With what smooth-bore gun could a 9 ft. target be hit at 1000 yds. 39 times out of 40?

What smooth-bore gun of 7-in. bore will throw a shell with 8 lbs. of powder bursting charge?

Listen to the words of one who has done more for the science of gunnery than any man who ever lived. Hear his voice from the grave; the words are nearly 100 years old, but the language is powerful and the spirit prophetic!

What said Benjamin Robins before he died?

"I shall therefore close this paper with predicting, that whatever State shall thoroughly comprehend the nature of rifled barrel pieces, and, having facilitated and completed their construction, shall introduce into their armies their general use with a dexterity in the management of them, they will by this means acquire a superiority, which will almost equal anything that has been done at any time by the particular excellence of any one kind of arms; and will fall but little short of the wonderful effects, which histories relate to have been formerly produced by the first inventors of fire-arms."

What single advantage has the smooth-bore over the rifle gun. Is it as accurate? No.

As generally effective? No.

As light? No.

In what then consists its superiority? "It has been proved by experiment to have a greater penetrating effect at short distances, and as naval actions will in future be fought at these short distances, we should arm our vessels with large smooth-bore guns, throwing heavy shot with a high velocity." But by what right is it assumed that naval actions are to be fought at short distances for the future? Is it because it suits the smooth-bore guns? No doubt it would have suited the *Macedonian* much better if she had fought her action with the *United States* at short distances than at long; but the American would not follow suit, and by keeping at a distance and taking advantage of his long range guns he gained the day. Exactly the same thing occurred in the action between the *Essex* and the *Phœbe,* except that in this case the British captain took advantage of his long range 18-prs., *chose the distance that suited his guns,* and in a very short time compelled his enemy to surrender.

In this action the 32-pr. carronades, which formed the armament of the *Essex,* would have been very formidable *at short ranges,* but they were almost useless at the distance at which the action was fought.

Again, it will be remembered in what a mortifying position a gallant British officer found himself on Lake Ontario in 1813, when he was pounded by long range guns, at such a distance that he had only *six guns in his fleet with which he could reply.* It is possible that this may occur again if the British navy be armed with an inferior weapon.

6. I admit that the rifle guns of the service at present are idle against iron plates properly constructed and firmly backed. Why? Because the projectiles they fire are animated with a low velocity. But why not correct this; it is easy to find a remedy. Put in more powder. Construct a muzzle loading rifle gun to throw a heavy projectile with a large charge of powder; you will get a higher initial velocity than the smooth-bore gives under the same circumstances; greater penetration, greater accuracy, in fact every advantage. The whole question now reduces itself to *iron.* That a large muzzle-loading rifle gun can be constructed on Sir W. Armstrong's excellent principle none who knows anything about the construction of these guns will for a moment deny.

The rifle gun might be made, moreover, lighter than the present 150-pr. smooth-bore, and yet throw the same weight of shot and use

the same charge. But to enable the gun to do this the area of the bore must be reduced, and consequently the strain will be increased. Will the *material,* of which the gun is composed, bear this strain? That is the whole question. *The iron must be of first rate quality;* it is *quality,* not *quantity,* which we want; and I have much too great an opinion of the engineering skill of this country to make me fear for the result. I have no doubt that the iron will be found, and that shortly we shall have our 150 and 300-pr. rifle guns, with an initial velocity of 1700 feet per second. The science of gunnery is but in its infancy, as far as relates to *the construction of* guns, and there is a wide field open in which a lover of his profession may gain credit for himself while he advances the interests of that arm to which he belongs.

There are difficulties in the way; we must take account of recoil; effect on the carriage; strain on the gun, &c. But these difficulties can be overcome by science and perseverance; and surely it is worth our while to try to effect this.

Even supposing that it be found impossible to make a rifle gun to bear the strain consequent upon throwing an elongated projectile with a high velocity, it would by no means be impossible to rifle a round shot or a short cylinder of the same weight as a spherical shot and so preserve some of the advantages of the rifle system, while attaining a high velocity. It is a great mistake to suppose that a rifle projectile is incapable of obtaining great velocity. *It all depends upon the charge with which it is fired.**

7. The following Tables shew the velocities, at different ranges, of various natures of shot and shell, and great pains have been taken to make these Tables perfect.

The Tables are based upon the following hypothesis:—

Supposing that the resistance of the air is

$$\rho = A\left(1 + \frac{v}{r}\right) v^2 \pi R^2,\dagger$$

the retarding force is

$$\frac{v^2}{2c}\left(1 + \frac{v}{r}\right) = \rho \frac{g}{P}.$$

* While this paper was passing through the press, an initial velocity of 1905 ft. was obtained by an elongated shot, of 6·2 lbs. weight, rifled on Mr Whitworth's principle, and fired, with a charge of 2 lbs., from his breech-loading 12-pr. gun.

† A = a constant = 0·0005137 for smooth-bores = 0·0003425 for rifles,
R = half the diameter of the shot,
π = 3·1415926,
v = the mean of the observed velocities at two points in the trajectory,

$$\text{or} \quad v = \frac{V + V'}{2}.$$

Then considering the motion to be horizontal, the range being x, and the time t, we shall have

$$\frac{dv}{dt} = -\frac{v^2}{2c}\left(1 + \frac{v}{r}\right),$$

$$\text{but } v = \frac{dx}{dt}; \text{ therefore } \frac{dv}{dx} = -\frac{v}{2c}\left(1 + \frac{v}{r}\right),$$

$$\text{or } dx = -2c\frac{dv}{v\left(1 + \frac{v}{r}\right)}.$$

Then integrating, we shall have

$$x = 2c \log \frac{\left(1 + \frac{V'}{r}\right)V}{\left(1 + \frac{V}{r}\right)V'}, \quad \text{or } 1 + \frac{r}{V} = \left(1 + \frac{r}{V'}\right)e^{\frac{x}{2c}}. *$$

This equation, the result of the French experiments at Metz, contains all the data necessary for computing the velocity of shot at different distances, the angle of elevation being small.

r = a constant = 1427 ft.
V' = initial velocity,
V = velocity at the range x,
c = a ballistic coefficient different for all natures of projectiles. This coefficient is given by tables computed for the purpose, and depends upon the diameter, form, and weight of the projectile.

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* This equation may be put under the following form:—

$$V = \frac{V'}{\left(1 + \frac{V'}{r}\right)e^{\frac{x}{2c}} - \frac{V'}{r}},$$

x is the distance, *measured on the prolongation of the axis of the bore*, but with small angles of elevation this distance may practically be said to equal the range.

The correction for this would bring the equation to this form,

$$V = \frac{V'}{\left(1 + \frac{V'\cos\phi}{r}\right)e^{\frac{x}{2c}} - \frac{V'\cos\phi}{r}} \cdot \frac{\cos\phi}{\cos\theta},$$

ϕ being the angle of projection above the horizontal plane,
θ the inclination of the trajectory at the point x, where the velocity is V;

$2C = \frac{P}{A\pi R^2 g}$, in which P = weight of shot, and g = gravity, the others as before.

When the initial velocity of rifled guns was not known from experiment, it was calculated by an empirical formula which I have found to give very good results.

This formula is something like that used by Dr Hutton, viz.,

$$V = 1400 \sqrt{\frac{C \times 6}{W}} \text{ in which}$$

$W =$ weight of shot in lbs.

$C =$ weight of powder in lbs.

$V =$ required velocity in ft.

It will be seen from the Tables what a very efficient gun the 150-pr. rifled gun would be. I look forward to seeing a gun of this description in the navy.

Its weight, as stated by competent authority, would not exceed 9 tons, and its penetrating power would be very great, at all distances.

In the late experiments at Shoeburyness with the 150-pr. smooth-bore gun against the *Warrior* target, it is generally supposed that the *shot* passed quite through the target. This was not the case. The iron plate or armour was penetrated, but in doing this the *cast-iron* shot was smashed to pieces, and whatever passed through was composed of pieces of the plate, and minute particles of the shot itself; the rest of the shot was buried in the woodwork, although this latter was bulged out, and the inner lining of the target ript and broken; but no *large* piece of iron passed through. Still the damage was very great, and a broadside of such guns would have destroyed the entire target. Now, by using a rifle gun, throwing a wrought-iron solid-headed shell, you would probably have the same effect as the round shot, besides bursting the charge, *at the back of the armour,* after the solid head had penetrated or punched a hole in it. A solid wrought-iron bolt with high velocity from a rifle gun would have penetrated clean through everything, leaving a hole of about the size of the shot to see daylight through.

What is wanted is *velocity;* if you sacrifice velocity to weight, you will only be able to keep knocking at the door, without entering. I believe the *Warrior* target would have stood a pounding from a 300-pr. rifle gun, if fired with the same low charges that we use in our service rifled ordnance.

The experimental velocities, given in the tables, were determined by me under the direction of the Ordnance Select Committee, with the electro-ballistic apparatus and may be taken as the true velocity of the different shot.

Table I.

TABLE SHEWING THE VELOCITIES OF DIFFERENT NATURES OF AMERICAN GUNS, AT VARIOUS DISTANCES.

Nature of gun.	Charge, lbs.	Projectile. Nature.	Projectile. Weight. lbs.	Initial velocity in feet.	Velocities, in feet, at 100 yds.	200 yds.	400 yds.	1000 yds.
42-pr.	10·5	shot	42·7	1600	1514	1435	1295	976
8-in. Columbiad	10·0	„	65	1375	1314	1240	1154	916
do do	10·0	shell	50	1570	1474	1360	1236	907
10-in. do	18·0	shot	127	1315	1270	1217	1150	957
do do	18·0	shell	101	1475	1409	1335	1233	970
15-in. do	40·0	„	315	1250	1210	1160	1080	890
11-in. Dahlgren	15·0	„	135	1200	1140	1090	1009	840
10-in. do	12·0	„	100	1150	1090	1036	938	720

Table II.

TABLE SHEWING INITIAL VELOCITIES OF RIFLE GUNS BY EXPERIMENT, AND CALCULATED FROM THE EQUATION

$$V = 1400 \sqrt{\frac{6 \times C}{W}}$$

V = velocity.
C = weight of charge.
W = weight of shot.

	Nature of gun.	Weight of charge. lbs.	Weight of shot. lbs.	Experimental velocity corrected for a uniform powder.	Calculated velocity.	Remarks.
Land Service.	12-pr. A.	1·5	11·75	1240	1225	Same diameter of shot, viz. 3·074 in.
	„	2·0	8·00*	1730	1715	
	40-pr.	5	41·5	1165	1190	
	110-pr.	12	111	1125	1127	
	„	12	103	1166	1170	
	„	16	111	1307	1302	
	„	14	111	1211	1217	
	„	12	150	995	970	
	„	11	174	892	862	
	150-pr.	40	150	...	1770	
	300-pr.	75	300	...	1715	

Table III.

TABLE SHEWING THE VELOCITIES OF DIFFERENT NATURES OF GUNS AT DIFFERENT DISTANCES, WITH THE LOSS OF VELOCITY CAUSED BY THE RESISTANCE OF THE AIR.

Nature of gun.	Charge.	Weight of shot.	Initial velocity.	Velocities, in feet, at 30 yds.	100 yds.	200 yds.	Lost in feet in 30 yds.	100 yds.	200 yds.
	lbs.	lbs.	ft.						
68-pr.	16	66	1579	1553	1488	1422	26	91	157
110-pr. rifled Armstrong gun	16	111	1307	1300	1287	1271	7	20	36
	14	111	1211	1205	1193	1178	6	18	33
	12	111	1125	1120	1109	1094	5	16	31
	12	103	1166	1160	1149	1133	6	17	33
	11	174	892	890	885	877	2	7	15
	12	150	995	992	983	974	3	9	18
150-pr. smooth-bore gun	40	150	1726	1710	1645	1586	16	81	140
300-pr. rifled gun	75	300	1715	1708	1690	1665	7	25	50
150-pr. rifled gun	40	150	1770	1762	1737	1704	8	33	66

* This is the service Royal Horse Artillery segment shell.

Table IV.

ABSTRACT SHEWING THE VELOCITIES OF DIFFERENT PROJECTILES, WITH DIFFERENT CHARGES.

Nature of gun.	Calibre.	Length of bore in calibres.	Charge.	Projectile.			Initial velocity.	Velocity at 1000 yds.
				Nature.	Mean weight.	Mean diameter.		
Smooth-bore.			lbs.		lbs.	in.	ft.	
68-pr. ……	8·12	14·0	16	spherical solid	66	7·91	1579	978
150-pr. ……	10·48	11·9	40	spherical solid	150	10·41	1726	1168·3
Rifled.								
110-pr. A. …	7·00	14·2	14	elongated solid	111	7·095	1211	1062·0
do ……	7·00	14·2	12	do	111	7·095	1125	980
150-pr. ……	7·52	19·0	40	do	150	7·50	1770	1485

Table V.

TABLE SHEWING THE "WORK DONE" AT DIFFERENT DISTANCES, BY DIFFERENT GUNS, THE 68-PR BEING TAKEN AS UNITY.

Nature of gun.	Charge.	Weight of shot solid.	"Work done" at 1000 yds.	"Work done" at 1000 yds. by 150-pr. rifled gun in comparison with 68-pr. and 150-pr. smooth-bore at 200 yds.
68-pr. smooth-bore …	16	66	1·00	
110-pr. Armstrong …	12	111	1·69	
do do …	14	111	1·98	
150-pr. smooth-bore …	40	150	3·24	
150-pr. rifled …………	40	150	5·24	
68-pr. smooth-bore …	16	66	…	1·00 at 200 yds.
150-pr. rifled …………	40	150	…	2·50 at 1000 yds.
150-pr. smooth-bore …	40	150	…	1·00 at 200 yds.
150-pr. rifled …………	40	150	…	0·88 at 1000 yds.

From this last table will be seen the value of rifled ordnance in comparison with smooth-bored at long distances.

Thus the 150-pr. rifled gun at 1000 yds. would be 2½ times as effective as the 68-pr. at 200 yds.; and the 150-pr. rifled at 1000 yds. is nearly as efficient as the 150-pr. smooth-bore at 200 yards. At 200 yds., the mean penetration of the 68-pr. into the *Warrior* target was about 2·5 in. At 1000 yds. the 150-pr. rifled gun would be more than double; and as the plate is only 4·5 in. thick, the probability is that it would be smashed.

Table VI.

SHEWING THE MEAN INITIAL VELOCITIES OF VARIOUS GUNS FIRED WITH DIFFERENT CHARGES. DETERMINED WITH NAVEZ'S APPARATUS.

Nature of Gun.	Calibre.	Length of bore in calibre.	Charge.	Projectile. Nature.	Projectile. Mean weight	Projectile. Mean diameter	Initial velocity.	Remarks.
			lbs.		lbs.	in.	ft.	
10-in. gun, 87 cwt.	10·00	10·9	12·00	hol. shot.	88·31	9·84	1292	
68-pr., 95 cwt......	8·12	14·0	16·00	shot	66·25	7·91	1579	
8-in. gun, 65 cwt.	8·05	13·0	10·00	com. shell	46·00	7·85	1487	
32-pr., 58 cwt......	6·37	16·8	10·00	shot	31·37	6·17	1690	
24-pr., 50 cwt......	5·82	18·0	8·00	,,	23·50	5·60	1720	
18-pr., 42 cwt......	5·29	19·2	6·00	,,	17·69	5·09	1691	
12-pr., 18 cwt......	4·62	16·1	4·00	,,	12·66	4·52	1770	
9-pr., 13 cwt.......	4·20	16·1	2·50	,,	9·37	4·10	1614	
Whitworth 12-pr. 9 cwt. breech-loading rifle gun	3·00 / 2·97	36·0	1·75	elongated shot	10·02	2·95	1464	
			1·75	,,	7·86	2·95	1654	
			2·00	,,	6·21	2·95	1905	
			1·25	,, spherical rifled	3·42	2·95	2210	
Britten, 32-pr. ...	6·37	16·8	5·00	elongated shell	50·36	6·24	1209	The competitive rifle cast-iron guns.
Jeffrey, 32-pr. ...	6·37	16·8	5·50	,,	48·06	6·26	1263	
Haddan, 32-pr. ...	6·37	16·8	7·00	,,	54·20	6·19	1277	
Lancaster, 32.pr.	6·95 / 6·35	16·2	6·00	,,	51·00	6·88 / 6·32	1246	
12-pr. Armstrong	3·00	24·5	1·50	seg. shell	11·69	3·074	1248	Shewing the effect of *reducing* the lead on the Armstrong projectile.
do	,,	,,	,,	,,	,,	3·010	1210*	
do	,,	,,	,,	,,	,,	3·010	1172	

This last Table has been added since this paper was read at the Royal Artillery Institution.

It has lately been stated publicly† that it was impossible to obtain a high velocity from a rifle gun when fired with the same relative charge as a smooth-bore; and that the friction, consequent upon the use of lead coating for Armstrong projectiles, was so great that no high velocity could be obtained by that arm. This is totally disproved by Tables II. and VI., and all such statements with regard to rifled ordnance are purely fallacious, and in no way borne out by any experimental facts.

* A band of lead 0·25 in. broad of the original diameter, viz. 3·074, left on the base.

† Journal United Service Institution, June, 1862.

REPORT

BY THE

MINISTER OF MARINE, PARIS, FEB. 9, 1859,

RELATIVE TO THE PROOF OF RIFLED CAST-IRON GUNS, AND THE REVISION OF FORMER REGULATIONS RESPECTING THE FABRICATION AND PROOF OF ALL IRON CANNON FOR THE IMPERIAL NAVAL SERVICE.

[Translated by Colonel GREATHED, C.B. and Colonel J. H. LEFROY, R.A., F.R.S. for the Ordnance Select Committee].

SIRE,

1. THE ordonnance of the 24th April, 1837, which regulates the technical operations relative to the manufacture, the proof, and the passing into the service of cast-iron guns, in the foundries of the Marine, has become insufficient, on account of the advances realized by an experience of twenty years in the metallurgy of iron applied to the production of cannon.

2. On the other hand, the introduction of cast-iron rifled guns requires special measures, which it is important to regulate.

3. To this end a commission, composed of officers of the Marine Artillery, who have more particularly served in the foundries, presided over by the inspector-general of that arm, has been charged, by my orders, to study the modifications and additions which it was necessary to apply to the text of the ordonnance of the 24th April, 1837.

The project of regulation, proposed by this commission and accepted by the council of the admiralty, regulates the classification of metals in the foundries, according to the origin and the differences in each lot.

By a new arrangement it is stipulated that in the proofs of metals entering into the composition of mixtures for guns, the cannon of 30, No. 1, which is the piece most used on board the fleet, shall be taken as the test, whereas until now the calibre of 8 has been exclusively employed for this purpose.

By the old regulation every unchambered gun, before being passed into the service, was made to bear the ordinary proof, viz. it was fired twice with two shots and a charge fixed at the half of the weight of the shot.

This mode of trial was of no use in testing pieces of inferior manufacture, which bore the proof, although strained by it; and we have cause to admit that this strain has contributed to the accidents which have happened in an after period in the service. The new proof of smooth-bores will be always made with two shot, but only with the quantity of powder fixed for the heaviest service charge of the piece which is to be proved.

The new regulation fixes with clearness and precision each detail of the management of the smelting furnaces and of the reverberating furnaces, as

well as all the stages of manufacture (*phrases de travail*) through which a gun passes until it is passed into the service.

In the second place, in order to make these dispositions agree with those inserted in the decree of May 1857, concerning the organization and the service of the establishments of the marine outside the dockyards, I would recommend to your Majesty to modify Article 28 of the decree of the 2nd of May, 1857, which gave to the inspector-general the right of giving direct instructions to the foundries, which right by the new regulation has been reserved exclusively to the minister.

(Signed)

HAMELIN,

Ministre Secrétaire d'Etat de la Marine.

Decree of the 9th February, 1859.

NAPOLEON, &c., have decreed,—

SECTION I.—*Plans and tracings. Mode of manufacture.*

Art. 1. Guns will be manufactured in conformity with the tables and tracings which have been approved by the minister of marine. It is expressly forbidden to communicate these without orders from him.

Art. 2. The guns will be cast from a second fusion.

Art. 3. They will still be cast solid, and without any sort of core.

Art. 4. They will be cast in sand moulds, which have been properly dried in the stove.

Art. 5. The proportions of the models should be such that, notwithstanding the contraction of the metal, the guns should have the dimensions prescribed by the tables. No exception is to be made, except in case of parts which are afterwards fitted.

Art. 6. No sealed pattern of a gun can be admitted for the service until the *procès-verbal* of its examination and verification has been approved by the minister.

The sealed patterns (*modèles définitifs*) will be made in cast-iron. The pieces which composed the parts in relief, such as cascable loops, trunnions and shoulders of trunnions, &c. will be in cast-iron, in bronze, or in wrought-iron.

The weight of the dead-head from the muzzle will be between one-third and one-fourth of the finished piece, except in the case of mortars. Every establishment on receiving an order for a new gun will send a tracing of the dead-head to the minister.

Art. 7. The mould-boxes will be cast-iron. They will be moulded with the greatest care, so that the fitting may be easy and that the different parts may have no play among themselves.

Art. 8. When provisional models are employed they will be made under instructions given by the minister.

SECTION II.—*On the management of smelting furnaces and foundries.*

Art. 9. In the treatment of ores, charcoal should be used as much as possible which is made from young wood of a good sort and of a moderate size. The charcoal should be sent to the foundry as soon as possible after it has been burnt, but it must not be placed for use until twenty-four hours after its arrival.

Art. 10. No mixture of ores intended for the manufacture of metal for guns can be definitively used until the metal produced has been submitted to the extraordinary proof. If in the course of founding it is found necessary to modify a mixture which has been adopted, the director will make his report to the minister as to the advantage of a fresh proof.

Art. 11. The definitive passing of ores will take place at the foundry. Still the director may, if he thinks right, send to the place of their extraction, or to their depôt, an officer of artillery or other agent of the establishment, in order that he may ascertain the source of the ores, and that he may assure himself as far as possible that they are the sorts and qualities acknowledged proper for the manufacture of guns.

In case of need an agent should be kept on the spot and charged to the department of marine.

Art. 12. The director will watch with the greatest attention that the different ores be not mixed, neither in the depôts nor during transport, nor in the yards of the establishment, where each sort should be placed separately and distinguished by a label bearing the name of the lode or vein from where it has come.

Art. 13. In each foundry a special registry will be kept of the situation of the ores of different sorts. This registry will be balanced every month.

Art. 14. A paved space will be reserved, on which the ores will be mixed in the proportion they will have to each other in the furnace.

Art. 15. The charcoal, ore, and flux with which the furnace is charged, will be the first measured and the two last separately weighed.

Art. 16. A covered space will be left near the mouth of the furnace, large enough to hold the quantity of mixed ores and flux necessary for twenty-four hours at the least, and the charcoal sufficient for the night work. This last will be prepared in advance, during the day.

Art. 17. The quantity of charcoal put into the furnace at a time will be the same throughout. This quantity will be fixed at the commencement of the founding and will be continued throughout.

Art. 18. No sudden change should be made if it can be avoided in the charge of ore or flux; but if the working of the furnaces requires that either one or the other be altered to any material extent, the metal run subsequently will not be classed as fit for the making of guns, during the whole time the derangement lasts.

Art. 19. Each time that the metal is run from the smelting furnace a standard pig will be made in a mould dried in the stove; its fracture will serve for the classification of all the pigs run at the same time.

Art. 20. In his reports on the furnaces, each month, the director will acquaint the minister with the changes which have been made, as well as with the causes of them. He will also specify the number and weight of the pigs produced during the abnormal working of the smelting furnace.

Art. 21. The rate of working the bellows will also be as regular as possible; and, except in case of special accidents, no change will be made without the order of the director.

Art. 22. When it appears at the beginning of a founding that the working of the smelting furnace is well regulated, and that the metal produced is fit for the manufacture of guns, this metal will be tried in the form of a gun of 30, No. 1, of the model 1849. The proof is laid down in Articles 71 and 72.

Art. 23. If the gun stands the proof, the employment of the mixture will be continued.

Art. 24. If the trial has an unfavourable result, the causes of failure should be investigated and remedied, after which a fresh trial will be made in the same manner.

If the gun succeeds, a report will be made to the ministry of the modifications which have been made in the second trial.

The pigs of iron which have been run between the castings of the two trial guns, and before the modifications introduced in the manufacture of the second gun, will be put aside, and only employed in the manufacture of guns under the orders of the minister.

Art. 25. When the working of the furnace has been regular, a receiving proof (*épreuve de recette*) shall be made by 400,000 kilos. (882,000 lbs.)* of metal made from the same mixture; and if, on the contrary, the working should have been irregular, and the director should have conceived doubts on the quality of the metal, he will communicate his fears to the minister, and demand authority to repeat the trial.

Art. 26. For the receiving proof of metal, the pigs of iron which are to form the trial gun will be taken at different periods of the manufacture, which is to be tried, and the intervals of time at which they have been run will as much as possible be equal.

Art. 27. The director will divide the workmen attached to the smelting furnaces into brigades, which will relieve each other by shifts, either by night only or by day and night, having regard to the good of the service, the habits of the country, and the comfort of the men.

Art. 28. The minister will organize, by means of the agents and military employed under his orders, a system of surveillance, with a view of ascertaining that every one conforms to the orders issued for the management of the furnace.

These agents will report the result of their observations to the officer of artillery whom the director has charged with the inspection of the smelting furnace.

Art. 29. The officer charged with the inspection of the furnace should himself, by frequent and unexpected visits, assure himself that the prescribed rules are observed, and that the surveillance ordered in the preceding Article is properly exercised. He shall always be present when the metal is run.

The other officers should also be present, if the director thinks fit.

Art. 30. The foreman of each brigade should note the proportions of each charge at the moment it is put into the furnace. He should warn the government foreman (*chef-ouvrier d'état*) of all the accidents which may happen to

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* "*Par quatre cent mille killogrammes de fonte.*" There appears to be some misprint here.—J. H. L.

the furnace. He should furnish him also with the documents required for the compilation of the journal of the foundry.

Art. 31. The government foreman will keep, under the eye of the officer charged with the inspection of the furnace, a register, in which he will insert the day and hour when the metal is run; the number and composition of the fillings of the furnace; the number of the mixture; the qualities of ores, charcoal, and flux employed; the product obtained; the mean pressure of wind at the nozzle of the bellows between two consecutive foundings; the diameter of the nozzle; the numbers of the pigs which have been run; the opinion passed upon the quality and the temperature of the metal; the accidents which may have happened, either to persons, to furnaces, or to blowing machines; in short, he will mention whatever may be calculated to furnish useful information as to the castings, at a subsequent period.

Section III.—*Classification and passing of metal.*

Art. 32. The metal will be placed separately in the yards (*parterres*) according to its origin. That which has the same origin will be divided into as many varieties (*nuances*)* as its physical character will permit to be established.

Art. 33. The classification of metal produced in the smelting furnaces of the foundries will be made at the same time for a considerable quantity of pigs of iron, once or twice a month at most. The classification of metal from the trade will be made on delivery, after its definitive acceptance.

Every time that the metal is run the standard pig will be broken, in order to judge of the working of the furnace.

Art. 34. The various shades of metal of the first fusion will continue to be designated by the denominations long used in the establishment. They will receive, in addition, a number shewing their order. No. 1 will be the greyest shade. The metal of the second fusion will receive the same numbers as those of the first fusion, to which they can be assimilated; or higher numbers, if the assimilation is not possible.

Art. 35. The metal of the second fusion will be classed according to the aspect of their fracture, comparing them as much as possible with metal of the same sort already classified.

Art. 36. The classification of the metal will be the care of the officer charged with the inspection of the smelting furnace, assisted by the government foreman and the master-founder. This classification will not be definitive till it has received the approbation of the director.

Art. 37. The metal which is bought at the works of the trade will be chosen by the director or the officers he may delegate, keeping clear of extreme shades (*nuance*) and textures, which ought not to be admitted in the manufacture of guns.

Art. 38. The metal to be passed should be of one founding, and produced from the same ores. Every lot should be of at least 80,000 kilogrammes (176,800 lbs.) This lot on delivery will be proved. In case the total delivery should be more considerable, proof should be taken on every 100,000 kilos. (221,000 lbs.) at the most.

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* *Nuance*, shade: as white, grey, mottled, but used to include all other physical distinctions.

The contractors will be required to keep and exhibit a regular registry of their castings certified by themselves.

Art. 39. Out of the metal chosen as specified in Art. 37 will be taken that which is required for the trial gun, as pointed out in Art. 40.

If the gun bears the proof, the lot will be received; otherwise, it will be rejected, as no more metal produced from the same founding can be received. Still a second proof may be made, under the authority of the minister, according to the results of which the director will give his opinion as to the reception or rejection of the said metal.

SECTION IV.—*Mixture of metals.*

Art. 40. The mixtures submitted for the approbation of the minister will be defined by their kind, their origin, and their shade (*nuance*). The castings from these mixtures will be assorted in such a manner as to cause them to take the shade which is recognized as good in the establishment for the calibres to which each of them is destined. The mixtures will be presented in the form of a schedule, on the following model:—

Name of Foundry. Mixture No.

Description, origin, and appearance of the metal.	Proportions by origin.	Number of the Class. *Nuance.*	Proportion by Class. *Nuance.*	Mean resulting Class. *Nuance.*	Remarks.
First melting.					
Second melting.					

When a mixture has been determined on, and proved in one or more calibres, it will be reproduced as exactly as possible, both in origin and shade, whenever guns of the same calibres are to be manufactured.

Art. 41. The mixture for the gun of 30, No. 1, used for passing the metal received, will contain at least 50 per cent. of the metal which is to be tried. The proportion of metal of other origin which enters into this mixture, will be determined in each foundry, so as to come as near as possible to the mixture approved for current manufactures. This mixture, when once determined upon, will remain as the standard in the foundry for each supply.

Art. 42. The mixtures of metals for the current manufacture of guns, cannot be admitted until they have borne the extraordinary proof of the calibres for which they are destined.

The mortars *à plaque*, of 32 centimètres (12·60 in.), will be cast of the mixture used in the foundry for the largest calibre experimented upon.

Art. 43. Whenever, in consequence of a change in the state of supplies, it is necessary to modify this mixture, the director will report to the minister, giving his reasons as to the advisability of a new proof. The

modified mixture will not be brought into use until authority shall have been received.

SECTION V.—*On the management of reverberatory furnaces, and on the manufacture of guns.*

Art. 44. No metal of first fusion, whatever be its origin, will be employed in the manufacture of guns, unless it shall have borne the extraordinary proof, as pointed out in Art. 72.

Art. 45. The coal employed in the manufacture of guns should be chosen of the best household quality (*première qualité pour la grille*), and the supply should contain as much lump coal as possible.

Art. 46. The furnaces will be charged in such a manner as to present the pieces most difficult to melt to the sharpest action of the fire. The metal will be placed upon bricks, so as to be surrounded in the most complete manner by the flames. The fire will be managed so as to obtain complete fusion and the highest temperature in the shortest possible time, and that care must be taken that simultaneous fusion should take place in the furnaces of which the products are to be united.

Care will be taken, before charging the furnace, to make a little barrier of loam perpendicular to the axis of the furnace. This barrier, which is intended to prevent the first fused metal from running to the vent before this part is well heated, will be removed at the fitting time by the founder.

During the fusion, the door by which the furnace is charged will not be opened, except in case of absolute necessity, and the stirring of the metal will be made, if it is considered desirable, through the small door (*porte du régard*) made for watching the progress of the smelting.

Art. 47. When possible, the maximum charge for furnaces actually in use, will be 2400 kilogrammes (5294 lbs.), and must not in any case exceed 2600 kilogrammes (5735 lbs.)

Art. 48. The government foreman will keep specially for the reverberatory furnaces a journal analogous to that pointed out in Art. 31 for the smelting furnaces. He will inscribe in this journal,—

(1) The numbers of the furnaces whose products have been united.

(2) The origin of the metal, weight, aspect of fracture, its shade and number, in order.

(3) The time employed in the fusion.

(4) The kind and quantity of the combustible employed.

(5) The appearance of the metal when run.

(6) The number of the piece cast.

(7) The other products obtained from the rough metal, slag, clinker, &c.

(8) The accidents which may have occurred during the fusion and subsequent operations.

He will add any useful details.

Art. 49. No gun is to be cast without the officer charged with the manufacture of metal castings being present; he will make a preliminary inspection of the preparatory arrangements, and will receive a report of the state and circumstances of the fusion from the government foreman. The other officers will be present at the casting if the director thinks fit.

Art. 50. The greatest care will be taken that the furnace contains stuff enough to cast the piece, and to give the proper length to the dead-head.

Art. 51. When the product of several furnaces is to be united in one casting, all the furnaces are to be unstopped at the same moment, so that the melted metal may become amalgamated in the one canal through which it must pass before entering the mould.

At the same time, the unstopping is to be made only when the whole of the furnaces have acquired a sufficiently high temperature.

Art. 52. Every piece of which the metal shall bubble (*bouillonnera*) after the casting, shall be rejected, if, after the breaking off the mould, the honeycombing shall be found anywhere but in the dead-head.

The mould is to be removed in not less than twenty-four hours after the casting; the piece still hot will be placed under shelter from the rain.

Art. 53. Whenever a gun is cast, it will receive a number inscribed in the registry of manufactures; this number, which will belong to the piece when finished, will be marked on the cascable and dead-head on the removal of the mould, even if the piece should have failed in casting. On this account, an uninterrupted series of numbers, which will recommence with each year, will be established in every foundry for every gun of the same nature.

Art. 54. When the mould has been removed, every gun will be scraped with the graver, to remove any sand which may adhere to it, as well as the seams, knobs, and other irregularities which alter the exterior form.

The gun will then be examined, and only passed to be finished in case its defects are within the limits of toleration.

Art. 55. After this examination the dead-head will be cut off, and the operations of centering, boring, and turning will be proceeded with.

The centering of the gun will be made in relation to its exterior surface, by making it turn on the beginning of the first reinforce, and on the end of the chase, and turning a centre on the cascable.

Art. 56. After the boring, and when it has been established that the dimensions come within the regulated limits, the swell of the muzzle will be turned. Account must be taken in this operation of the diameter of the base-ring of the breech, and of the eccentricity in the vertical plane of fire. The turning of this part will be so performed as to have *the angle of the line of metal constant.*

The other operations of finishing the gun will then be proceeded with; last of all the vent will be drilled; its exterior orifice must be in the vertical plane.

Art. 57. There will be engraved on the breech, following its contour at equal distance from the base-ring and cascable,—

(1) The number of the piece.

(2) Designation of the calibre.

(3) Weight in kilogrammes.

(4) Name of the foundry.

(5) The date.

Art. 58. The officers of artillery and government foreman will watch these operations, and assure themselves, by frequent verifications during the process of boring, that the borers have no irregular motion, shewing that their working is deranged.

Art. 59. The government foreman will keep a note-book for the purpose of recording the result of the examinations prescribed by Articles 54 and 56, as of any others to which the piece is subjected.

Section VI.—*Examination, ordinary proof, and passing of smooth-bore guns.*

Art. 60. The guns being finished, they will, before being proved, be subjected to a general examination, made in conformity with special instructions given to that effect by the minister. The object of this examination is to record in positive terms all the defects of dimensions, or others which the piece may have.

Art. 61. The guns which, in the examination directed in the preceding Article, have not shewn defects exceeding toleration, will be submitted to the ordinary proof, following as much as possible the order in which they were cast.

In this proof the guns will be placed on the sledge-carriages in use, and they will be pointed at the angle nearest to 3°, but always in such a manner that the shot may surely strike the butt.

Art. 62. A warning signal gun will be fired before commencing the proofs; and during their course a red flag will remain flying on an elevated spot, so as to be easily seen by the neighbourhood.

The guns will be fired with a slow-match, which will permit the gunners to be under cover, in case of a gun bursting. In short, no precaution against accident is to be neglected.

Art. 63. The powder, cartridge-bags, and spherical projectiles used in the proofs, must fulfil the conditions required by the naval service. The cartridge-bags will be made on the mandril which is the regulated one for the naval service at the time.

The wads will be of hay, and will weigh one-thirtieth of the weight of the spherical shot; they will be one calibre in length and diameter.

The powder will be weighed and put into cartridge-bags in presence of one of the officers of the commission and the government foreman.

Art. 64. The ordinary proof for all guns (with the exception of mortars) will consist in two shots fired consecutively with the largest charge of powder used in the naval service, in conformity with the schedule annexed to the present decree.

Art. 65. For guns, howitzers of 30, and carronades, the charge will consist and will be fired as follows:—The indicated charge of powder, a wad of hay, two shot and a second wad of hay—ram down twice on each wad. For howitzers the charge of powder indicated, a wad, a spherical solid shot of the calibre of the shell, and a second wad on the projectile.

Art. 66. After the two rounds have been fired, as prescribed in Art. 64, the gun will be cleaned and searched to find out the effect of the proof. The result of this examination will be noted down in the *procès-verbal* of the proof.

Art. 67. All the operations, inspections, and proofs prescribed in the present section shall take place in the presence of a committee, presided over by the director of the foundry, and composed of all the officers of artillery employed in the establishment together with the *chef-ouvrier d'état*. The civil officer *agent administratif* will be warned and may attend and take part when he thinks fit.

Art. 68. All operations, examinations and proofs prescribed under the present head, will be recorded in a separate *procès-verbal* for each sort of gun of the same calibre. This *procès-verbal* will comprise not only the pieces which have been proved and passed, but those also which have been rejected, from whatever motive; or those which, being in the case specified by Art. 83, have not yet been classed by the minister, so that the series of the numbers may not be interrupted.

Art. 69. The director will address to the minister a *précis* of all the *procès-verbaux*. He will send the guns away only when he hears from the minister that the *procès-verbaux* have been approved, and the guns may be dispatched. He will send with the guns to the *prefect maritime* of the port a copy of the *procès-verbaux*.

Art. 70. If a gun burst in the ordinary proof, the director will report immediately to the minister, and give an account of the causes of the accident.

SECTION VII.—*On the extraordinary proof and the proof of continuous firing.*

Art. 71. Extraordinary proofs will be made,—

(1) On passing metal.

(2) On proving the mixtures of current manufacture.

(3) When a gun has burst with the ordinary proof.

(4) When a new nature of gun is to be introduced into the naval service.

(5) Each year, on one or more guns out of the number ordered, according to the number.

Whatever may be the end proposed in making this proof, it must never be made except under orders of the minister, except in the cases anticipated in Articles 20, 22, and 25. Every piece submitted to this proof should have undergone the ordinary proof.

Art. 72. Guns will be proved partly with spherical shot, partly with cylinders, and a series of increasing charges, as pointed out in the schedule of proofs annexed to the present decree. A wad of hay will be put on the cartridge, and one on the last projectile: two blows will be struck home on the wad. The number of rounds that guns should bear before being passed will be hereafter fixed, and after the results of the first extraordinary proofs.

Art. 73. The extraordinary proofs of shell guns and carronades will be made in an analogous manner, but with a single charge of powder equal to the heaviest charge in use in the naval service. The howitzer of 22 centimètres (8·66 in.) will be equally proved with the heaviest charge of powder and with cylindrical projectiles. The mortar *à plaque* of 32 centimètres (12·60 in.) will not undergo the extraordinary proof.

Art. 74. The spherical shot will be those of the service. The cylindrical projectiles will have the same windage as those of rifled guns of the same calibre; and for smooth-bores a windage in proportion to that of rifled guns.

Art. 75. When the extraordinary proof has been ordered in consequence of the bursting of a gun in the ordinary proof, this proof will be applied to another gun taken from among those which were tried at the same time as that which burst, and cast from the same metal under the same circumstances. The orders of the minister will then be taken, a report having been made to him of the proof in the form prescribed by Article 76.

Art. 76. A special *procès-verbal* will be made of every extraordinary proof. This *procès-verbal* will indicate the weight, origin, kind, and shade (*nuance*) of the metal which has been used in the manufacture; the duration of the fusion, and the important incidents of the casting.

It will shew the result of the examination of the gun, the greater or less facility which has been found in the boring, and the time employed in that operation; the duration of the proof; the number of rounds it has borne; the number of pieces into which it has burst; also the shade of the metal observed at the fracture of the dead-head, and in the pieces of the reinforce.

The title of the *procès-verbal* will shew the object proposed in making the proof; the circumstance which occasioned it, as well as the facts which have been established.

Art. 77. When a new nature of gun is introduced into the naval service, two pieces of this nature will be made in each foundry; one will be put to the extraordinary proof, the other to that of continuous firing.

Art. 78. The proof by continuous firing will consist in firing carried on under the ordinary conditions of service with heaviest service charge, and continued up to the number of rounds directed by the minister. The piece will be washed and examined after every 25 rounds. The interval between each should not be less than a minute and a half, and not more than two minutes.

Art. 79. The arrangements prescribed by Articles 62, 63, 67, and 73 will be observed in the extraordinary proofs. All extraordinary proofs will be made in the foundries, unless special orders are given to the contrary.

The proofs by continuous firing will be generally made in the ports, and by preference at Gavre.

Section VIII.—*Rifled cannon.*

Art. 80. The manufacture of rifled cannon will be subjected, as to their founding, boring, and finishing, and all that belongs to it, to the regulations contained in the present decree.

In addition, according to the requirements of the establishment of rifled guns which will compose this artillery, special ministerial instructions will be given.

Art. 81. The ordinary proof of rifled cannon will consist of two rounds with the heaviest service charge, a wad rammed down on the cartridge, and a service ogivo-cylindrical shot.

The extraordinary proof of rifled cannon will be carried out upon these guns unrifled, like that of smooth-bored guns of the same calibre.

The first proof will establish the number of rounds to which the extraordinary proof of these guns ought to be limited. The proofs by continuous firing will be executed under the conditions of the service, and in conformity with particular orders. And in all that is not foreseen, the Section VI. of the present decree will be conformed to.

SECTION XI.—*General arrangements.*

Art. 82. When, in the course of manufacture, or after proof, a gun presents defects exceeding the toleration, but which do not appear to render it unfit for service, the director will report to the minister and await his orders. In the meantime this gun will be considered on sufferance, and its completion be suspended.

Art. 83. Every gun which has defects exceeding toleration, and which would render it unfit for the service, will be rejected. One of the trunnions will be immediately broken, if it is a gun or a howitzer; if it is a carronade, a large piece will be broken off the loop.

Art. 84. No change will be made, even as an experiment, in the ordinary process of manufacture, in the disposition of the furnaces, or in those of the principal machines, without the authority of the minister.

Art. 85. When the minister shall have authorized the use of the smelting furnace the director will report to him the arrangements he has made concerning it, and will await his instructions before lighting the fires.

Art. 86. The director will conform to the instructions which will be given him by the minister concerning all operations not foreseen by the present decree.

Art. 87. When a gun bursts on service, a report will be made to the minister, who, after receiving information, will decide whether one or more guns of the same manufacture should be proved, and the mode of proof to be employed.

Art. 88. The former decisions and regulations, and particularly the ordonnance of the 26th November, 1786, and that of the 24th April, 1837, are hereby abolished.

Art. 89. The ministerial instructions, 29th April, 1837, will be revised and put in accordance with the prescriptions of the present decree, of which the execution is confined to our minister Secretary of State for the Marine.

(Signed) NAPOLEON.

HAMELIN.

PARIS, Feb. 9, 1859.

Table of Ordinary Proofs.

Nature of Ordnance.	Weight of charge for each round. kil.	lbs.	Nature and number of projectiles for each round.	No. of rounds to be fired.
Canon de 50	8·33	18·38	2 spherical solid shot	2
„ de 36, No. 1	6·00	13·23	id	id
„ de 30, Nos. 1 and 2	5·00	11·03	id	id
„ de 30 rayé, année 1858	3·50	7·72	1 ogivo-cylindrical shot	id
„ de 30, No. 3	3·00	6·62	2 spherical solid shot	id
„ de 30, No. 4	2·50	5·51	id	id
„ de 24, No. 1	4·00	8·82	id	id
„ de 18, Nos. 1 and 2	3·00	6·62	id	id
„ de 12, Nos. 1 and 2	2·00	4·41	id	id
„ de 12, No. 3	1·50	3·31	id	id
Canon-obusier de 30	2·00	4·41	id	id
Obusier de 22 centimètres, No. 1	3·50	7·72	1 spherical solid shot, same diameter as shell	id
„ „ No. 2	3·00	6·62	id	id
Mortier de 32 centimètres à plaque	14·00	30·94	1 shell,* extra weight, 94 kil.	4
Caronade de 36	2·00	4·41	2 spherical solid shot	id
„ de 30	1·60	3·53	id	id
„ de 24	1·30	2·87	id	id
„ de 18	1·00	2·21	id	id
„ de 12	0·65	1·43	id	id

* Shell for coast service.

Note.—The cartridges and the projectiles will be the same at those actually in use by the naval service, with the exception of the projectile for the howitzer of 8·66 in., which will be specially prepared for the proof of this gun.

Two hay-wads will be used in each round for all guns; one on the powder, the other on the last projectile, with the exception of mortars, which are fired without wads, and also rifled guns, which require but one, on the powder.

The hay-wads will be rammed home with two blows.

The hay-wad will be one-thirtieth of the weight of the spherical solid shot, and will be in length and thickness the diameter of the shot.

Table of Extraordinary Proofs.

Nature of Ordnance.	Weight of charge for each round. kil.	lbs.	Nature and number of projectiles for each round	kil.	lbs.	No. of rounds to be fired.
Canon de 50	8·33	18·38	2 spherical solid shot		....	20
	id	„	1 cylindrical shot, weighing	50	110·28	20
	id	„	1 „ id „	75	165·43	20
	12·50	27·57	1 „ id „	75	165·43	20
	15·00	33·09	1 „ id „	75	165·43	To bursting
Canon de 36, No 1	6·00	13·23	2 spherical solid shot		....	20
	id	„	1 cylindrical shot, weighing	36	79·41	20
	id	„	1 „ id „	54	119·11	20
	9·00	19·85	1 „ id „	54	119·11	20
	10·80	23·83	1 „ id „	54	119·11	To bursting
Canons de 30, Nos. 1 et 2, et canon de 30 rayé	5·00	11·03	2 spherical solid shot		....	20
	id	„	1 cylindrical shot, weighing	30	66·17	20
	id	„	1 „ id „	45	99·26	20
	7·50	16·54	1 „ id „	45	99·26	20
	9·00	19·85	1 „ id „	45	99·26	To bursting
Canon de 30, No. 3	3·00	6·62	2 spherical solid shot		....	20
	id	„	1 cylindrical shot, weighing	30	66·17	20
	id	„	1 „ id „	45	99·26	20
	4·50	9·93	1 „ id „	45	99·26	20
	5·40	11·91	1 „ id „	45	99·26	To bursting
Canon de 30, No. 4	2·50	5·51	2 spherical solid shot		....	20
	id	„	1 cylindrical shot, weighing	30	66·17	20
	id	„	1 „ id „	45	99·26	20
	3·75	8·27	1 „ id „	45	99·26	20
	4·50	9·93	1 „ id „	45	99·26	To bursting

Nature of Ordnance.	Weight of charge for each round.		Nature and number of projectiles for each round.			No. of rounds to be fired.
	kil.	lbs.		kil.	lbs.	
Canon de 24, No. 1	4·00	8·82	2 spherical solid shot		....	20
	id	„	1 cylindrical shot, weighing	24	52·94	20
	id	„	1 „ id „	36	79·41	20
	6·00	13·23	1 „ id „	36	79·41	20
	7·20	15·88	1 „ id „	36	79·41	To bursting
Canons de 18, Nos. 1 et 2	3·00	6·62	2 spherical solid shot		....	20
	id	„	1 cylindrical shot, weighing	18	39·70	20
	id	„	1 „ id „	27	59·55	20
	4·50	9·93	1 „ id „	27	59·55	20
	5·40	11·91	1 „ id „	27	59·55	To bursting
Canon de 12, Nos. 1 et 2	2·00	4·41	2 spherical solid shot		....	20
	id	„	1 cylindrical shot, weighing	12	26·47	20
	id	„	1 „ id „	18	39·70	20
	3·00	6·62	1 „ id „	18	39·70	20
	3·60	7·94	1 „ id „	18	39·70	To bursting
Canon de 12, No. 3	1·50	3·31	2 spherical solid shot		....	20
	id	„	1 cylindrical shot, weighing	12	26·47	20
	id	„	1 „ id „	18	39·70	20
	2.25	4·96	1 „ id „	18	39·70	20
	2·70	5·96	1 „ id „	18	39·70	To bursting
Canons-obusiers de 30	2·00	4·41	2 spherical solid shot		....	20
	id	„	1 cylindrical shot, weighing	30	66·17	20
	id	„	1 „ id „	45	99·26	To bursting
Obusiers de 22, No. 1	3·50	7·72	1 „ id „	60	132·34	10
	id	„	2 cylindrical shot, each weighing	60	132·34	10
	id	„	3 „ id „		....	10
	id	„	4 „ id „		....	To bursting
Obusiers de 22, No. 2	3·00	6·62	1 cylindrical shot, weighing	60	132·34	10
	id	„	2 cylindrical shot, each weighing	60	132·34	10
	id	„	3 „ id „		....	10
	id	„	4 „ id „		....	To bursting
Caronade de 36 ...	2·00	4·41	2 spherical solid shot		....	20
	id	„	1 cylindrical shot, weighing......	36	79·41	20
	id	„	1 „ id „	54	119·11	To bursting
Caronade de 30 ...	1·60	3·53	2 spherical solid shot		....	20
	id	„	1 cylindrical shot, weighing	30	66·17	20
	id	„	1 „ id „	45	99·26	To bursting
Caronade de 24 ...	1·30	2·87	2 spherical solid shot		....	20
	id	„	1 cylindrical shot, weighing	24	52·94	20
	id	„	1 „ id „	36	79·41	To bursting
Caronade de 18 ...	1·00	2·21	2 spherical solid shot		....	20
	id	„	1 cylindrical shot, weighing	18	39·70	20
	id	„	1 „ id „	27	59·55	To bursting
Caronade de 12 ...	0·65	1·43	2 spherical solid shot		....	20
	id	„	1 cylindrical shot, weighing	12	26·47	20
	id	„	1 „ id „	18	39·70	To bursting

NOTE.—For ordinary charges the cartridges will be the same as those of the service; and for stronger charges they will be prepared upon mandrils of the same diameter and of the necessary length.

The spherical solid shot will be those of the service.

The cylindrical proof shot will have the same windage as the ogivo-cylindrical shot of the same diameter. They will be rounded at both ends.

The proof cylinder of the howitzer, and the cylinder equal to two round shot used in the proof of all other guns, will be a calibre and a half in length. A cavity will be made in each, for regulating the weights of these projectiles.

Two hay-wads will be used in each round, one on the powder, the other on the last projectile.

The wads will be rammed home with two blows.

The weight of the wad will be one-thirtieth of the spherical solid shot, and of the same length and diameter as the gauge of the bullet.

For the proof of howitzers of 8·66-in., the cylindrical shot will be separated by a wooden bottom, 10 centimètres (3·94-in.) long.

After each series of 10 rounds the practice will be suspended, the gun scraped, washed, and examined; an impression of the orifices of the vent will be taken, and the increase in the passage of this latter be measured by the cylindrical sound.

The headings of this table being only provisional, careful study and observation will be made during the proofs, with a view to any modifications which may be advantageously applied to it, to determine the most advantageous plan of executing these proofs, and to regulate as much as possible the proper intervals of time between each stage (*séance*), each series, and each round of the proof.

Every extraordinary proof will be preceded by the ordinary proof, whatever the nature of the gun.

J. H. L.

ACCOUNT

OF

EXPERIMENTS AGAINST IRON PLATES, CARRIED ON AT SHOEBURYNESS, ON THE 8TH APRIL, 1862.

[FURNISHED BY CAPTAIN E. J. BRUCE, R.A.]*

I. Experiment carried on against the *Warrior* target.†

II. Experiment against the *Committee* target,‡ on which latter, since previous experiment on the 4th March, 1862, the following alterations have been made: viz.

Upper Plate.—On the left half of this plate, rivets, having conical heads, had been substituted for bolts, and vulcanized india-rubber washers inserted behind the bolt-heads on the right half of the plate; there being no intervening substance between the plate and the skin. This part of the target therefore remained as iron on iron.

Lower Plate.—One-quarter inch thickness of felt dipped in tar had been inserted between the skin and half the length of the plate on the left side, the fastenings being rivets. On the right half of the plate, ¼-in. thickness of vulcanized india-rubber had been inserted between the skin and plate; bolts having nuts and india-rubber washers were used for fastenings. A few of the bolts had spun-yarn instead of india-rubber washers.

Centre Plates.—These plates had suffered most from the firing at the late experiment, and had been refastened with bolts having four washers (three of lead and one of iron) under the bolt-heads; they were not fired at, on the present occasion.

RANGE 200 yds.

"WARRIOR" TARGET.

No. of round.	Nature of ordnance.	Charge in lbs.	Nature of projectile.	Front.	Back.
1	300-pr.§	40	150 lbs. spherical cast-iron.	Hit on the junction of the lower and centre plates to the left of the port-hole. Smashed in the plate, making a hole 1 ft. high by 14 ins. The bulge was 3′ 1″ long × 1′ 8″ high. A crack 2′ 7″ long, across the top of the bulge, and a huge crack extended in a zigzag direction across the plate and through its thickness. The tongue and groove was broken only at the actual hole.	Inner skin fractured and bulged in; strong iron ribs broken in two; two nuts of bolts broken off.

* For several particulars thanks are due to Captain Harrison, R.A.
† See pp. 30 and 43. ‡ See p. 44.
§ *i.e.* this gun, *if rifled*, would fire an *elongated* shot of 300 lbs.

No. of round.	Nature of ordnance.	Charge. in lbs.	Nature of projectile.	Front.	Back.
2	300-pr.	40	150 lbs. spherical cast-iron.	Hit the target a little to the right of the previous shot. 3′ 2″ of the plate smashed and the wood exposed. A piece of the plate 2′ 3″ × 11″ broken away.	Skin broken up; a second rib broken. The former broken rib driven clean out and bent back at a considerable angle and smashed. Portions of shot, wooden backing, &c. driven right through. Large irregular *hole.* The great square timbers (side view) forming the backing to the plates were shattered, and the fibre of the wood seemed to be drawn through the entire length of the beams by the passage of the shot at the place of fracture and penetration.
3	"	50	"	Struck the lower plate on the right side of the port-hole. Made a clean hole 11″ diameter. Centre of the hole 1′ 3″ from the bottom of the plate. Two cracks extended to the bottom of the plate, but independent of the shot hole.	Nothing perceptible but a few splinters of wood raised up from the foot of the target, and a few nuts loosened. One broken off.
4	"	"	"	Hit the top plate in the centre of the right side. Made a hole 11″·5 diameter, and the shot broke up in it. Depth of hole 13″.	Struck where the inside skin was supported at top by two beams with a total of about 2 ft. square solid timber (thus hiding the full effect of the shot); but, where it *could* be seen, the skin was bulged in, and the 2 ft. of solid timbers supporting were cracked right through. Also heavy beams likewise giving support (at right angles to target) were started, and solid granite blocks in rear were shaken. To be regretted that the back of the target, at the seat of the injury, could not be seen, being hid by the beams referred to.*

* The "Warrior" target has since been taken to pieces, and it has been clearly ascertained that this shot, though it cracked the inside skin, penetrated through the teak backing to the extent of 13 in. only, leaving a depth of 5 in. of the wood backing into which *no fragment of the shot had forced its way.*

"COMMITTEE TARGET.

Five rounds were fired at the *left* side of lower plate.

No. of round.	Nature of ordnance.	Charge in lbs.	Nature of projectile.	Front.	Back.
1	68-pr.	16	shell filled with sand	Struck on junction of middle and lower plates 4′ 4″ from left side of the target, half the indent being on each plate. Depth of indent 1″·8, diameter 10″.	A few small rivets, merely uniting the angle-iron to skin of ship, were broken off. A slight crack (very slight) on one of the angle-irons where it joined one of the iron supporting ribs. Some of the lead washers of the through bolts (in the neighbourhood of the blows) drawn thinner and worked loose; india-rubber washer much compressed.
2	110-pr.	12	"	Struck the target 2′ 3″·75 from the left side and 2′ 5″ from the bottom of the lower plate. Made a slight indent. A bolt started.	
3	"	"	"	Hit lower plate 3′ 11″ from the left side and 2′ 7″ from the bottom, making a slight indent.	
4	"	"		Struck on the centre plate.	
5	68-pr.	16	"	Hit on lower edge of the port-hole 7″ from the left side. A piece of the plate 9″·5 long and 2″ wide broken off and a crack 6″ long extended from a bolt-hole in the lower plate. Indent 1″·7. Diameter, 9″·5	

Ten rounds were fired at the *right* side of lower plate.

No. of round.	Nature of ordnance.	Charge in lbs.	Nature of projectile.	Front.	Back.
6	110-pr.	12	shell filled with powd.	Struck the centre plate.	Two bolt-heads broken off, but none gone in the bottom plate; where a sheet of vulcanized india-rubber intervenes. No other trace of injury.
7	68-pr.	16	"	Hit on the junction of centre and lower plates, and 1′ 95″ from the port. Depth of indent 1″·2, diameter on lower plate 4″.	
8	110-pr.	12	"	Hit the plate 7″ from the top, and 2 ft. from the port. Slight indent.	
9	"	"	"	Hit the plate 14″ from the top, and 3′ 7″ from the right side of the target. Slight indent.	
10	68-pr.	16	"	Hit the plate 8″·5 from the top, and 1′ 9″·5 from the right side. The second and third bolts from the right in the top row started, the latter 5″. Indent 1″·25, diameter 9″.	
11	110-pr.	14	solid shot	Hit the lower plate on the right side 1′ 11″·5 from the port, and 8″·5 from the top. Indent 2″·05. A crack 16″ long across the centre of the bulge.	Two ribs broken clean through. Five angle-irons broken. Skin fractured and forced out in pieces behind, along with parts of the india-rubber sheeting. One of the through bolts had the head broken off.
12	68-pr.	16	"	Hit the plate 3″ from the top and 2′ 11″ from the port. Indent 2″·3, diameter 8″. A crack 10″·25 long across the bulge.	
13	110-pr.	14	"	Struck the centre plate.	
14	"	"	"	Hit the plate 9″ from the top, and 3′ 5″ from the port on the top of a bolt which had previously been started. The bolt was drawn. Indent 2″·55, diameter 6″·5. A crack 7″·5 long extended from the bulge.	
15	120-pr.	20	140 lbs. shot.	Hit the plate 1′·5″ from the top, and 4′ 11″ from the right side. Indent 2″·9, diameter 8″. Slight crack across the centre of the bulge.	

	No. of round.	Nature of ordnance.	Charge in lbs.	Nature of projectile.	Front.	Back.
	16	110 pr.	10	flat-headed bolt 200 lbs.	Did no apparent damage.	Slight bulging of skin merely.
	17	,,	,,	,,		
	18	,,	,,	,,		
Salvo.	19				Fired at left side of the lower plate. Did no apparent damage.	Did not fire together. No visible effect.
	20	,,	,,	,,		
	21					
Salvo.	22	120-pr.	20	140 lbs. shot.	Hit the left side of lower plate 1′ 9″·5 from the bottom, and 3′ 10″·5 from the left side. Depth of indent 2″·25, diameter 7″. A crack across the bulge.	Huge fracture with hole. A large piece of solid plate driven through with other debris. Two ribs broken across. Skin bulged out, torn, and bent up nearly at right angles. A through bolt driven out with the rest. Solid timber support at foot of target cracked through.
	23	110-pr.	14	solid shot	One 110-pr. of this number struck the centre plate.	
	24	,,	,,	,,	These shot made a hole (triangular) with a base 1′ 7″ long, and sides 1′ 10″ long, on left side of lower plate. A wide crack extended from the bottom of the hole through some old shot marks to the bottom of the plate.	
	25	,,	,,	,,		
	26	68-pr.	16	,,		
	27	,,	,,	,,	Hit just below the hole made as above. Indent 2″, diameter 9″.	
					Six shots were fired at top plate on *left* side of target.	
Salvo.	28	,,	,,	,,	Hit on a rivet which was forced out. Indent 2″·3, diameter 9″.	One rivet was driven out, but not broken. 14″ of the backing of the skin broken off. One bolt with spun yarn washer, driven back and part of the washer destroyed, but bolt apparently uninjured.
	29	,,	,,	,,	Hit the plate 1′ 4″ from the top, and 5′ 1″ from the left side. Indent 2″·1, diameter 9″.	
	30	110-pr.	14	,,	Hit 6″ from the top. Indent 2″·35. A crack extended from a bolt-hole to the top of the target.	
	31	,,	,,	,,	Hit 1′ 3″ from the top. Indent 2″·05.	
	32	,,	,,	,,	Hit 1′ 8″ from the top. Indent 1″·8 Two cracks across the bulge.	
	33	120-pr.	20	140 lbs. shot.	Missed the plate.	

Fired at *right* half of top plate; four shots struck the plate.

	No. of round.	Nature of ordnance.	Charge in lbs.	Nature of projectile.	Front.	Back.
Salvo.	34	110-pr.	14	solid shot.	Made an indent 2″·5.	18″ of the backing of the skin was destroyed. One rib broken across, and two angle-irons.
	35	,,	,,	,,		
	36	,,	,,	,,	Two shot struck on a rivet 6″ from the bottom and drove it out. A huge crack extended to the bottom of the plate.	
	37	68-pr.	16	,,		
	38	,,	,,	,,		
	39	120-pr.	20	140 lbs. shot.	Hit 1′ 5″ from the bottom of the plate. Made an indent 2″·1. Diameter 7″. Huge crack across the bulge.	
					The lower plate had buckled 1 in. on the right side, but the bolts were uninjured. The left side was buckled 1″·25, but the rivets were uninjured.	

REMARKS

ON

PERMANENT FORTS AND MOVEABLE FLOATING BATTERIES AS MEANS OF DEFENCE AGAINST THE BOMBARDMENT OF OUR ARSENALS AND DOCKYARDS BY AN ENEMY'S SHIPS.

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THE new mode of protecting ships of war from artillery fire by means of wrought-iron plates, will, in my opinion, materially affect the relative values of permanent forts and moveable floating batteries in preventing the bombardment of our arsenals and dockyards; and, in certain cases, I believe that fixed batteries will be found useless; and, unless we are amply provided with powerful and well-protected moveable floating batteries, some of our dockyards will be at the mercy of an enterprising enemy who may desire their destruction.

In discussing this matter, which is one of vital importance at the present time, it will be better to take a particular example rather than to deal in generalities; and a better case cannot be chosen to illustrate the subject, than the one which has lately been brought so prominently before the public, namely, the harbour defences of Portsmouth. The first question is, then—Will the combined action of these Portsmouth land batteries, afford any effectual protection to the dockyard and government storehouses, against bombardment by an enemy furnished with properly constructed iron-clad mortar vessels and gun boats?

By a reference to the plan which accompanied the Report of the Royal Commissioners appointed to consider the defences of the United Kingdom it will be seen that the enemy's ships need not come, at any time, nearer to either of the forts than 1000 yds.; that at this, the shortest range, they would only be exposed to the fire of the two Spithead forts for a very short time; and, further, that after steaming rapidly between these forts, they will then be at liberty to take up positions about 4000 yds. from the dockyard, and about 2000 yds. from any of the existing or contemplated fixed batteries.

Under these circumstances, is it probable that an enemy would be inconvenienced to any serious extent by the fire from the batteries, during the time they are working destruction in the dockyard and storehouses?

In considering this point, it must be recollected, that the mortar vessels and gun boats would, without doubt, be constructed so as to present but a comparatively small object to fire at; and that they would be in constant motion during the time they are exposed to our artillery fire.

First, as to the probability of hitting the enemy's ships.

Upon this point, no doubt, great difference of opinion will exist, my own belief is—and I entertain very decided views on the subject—that, under all those comparatively unfavourable circumstances which it may be fairly assumed would attend the service of the guns, &c.,—even supposing no opposition is offered to the fire of the forts, and that it is in the daytime when the

operations are being carried on—the number of shot striking the ships would be very small indeed, as compared with the number fired; for, however perfect a gun may be in respect to accuracy of shooting, it would rarely be fired under the necessary conditions of "elevation" to strike a moving object, such as a mortar vessel or gun boat, at a range of 2000 yds.,—and even if we assume, for the sake of argument, that the shot which strike will penetrate, the enemy would, I believe, be able as a rule to effect their object before being obliged to discontinue their fire. For, unless some vital part sustains serious injury, there is every reason to believe, as we know would be the case with a wooden ship, that the iron-clad vessel might continue its offensive operations after it had been repeatedly struck by our shot.

Secondly, as to the effect likely to be produced on the iron-clad vessel by the artillery from the forts.

This is a matter about which little doubt need be entertained, in fact, it is one which will almost admit of exact demonstration. In considering this part of the subject we may, of course, leave out of account the present guns of the service; for as they have failed to penetrate a target similar in construction to the sides of Her Majesty's Ship *Warrior* even when fired at 200 yds. range, and when placed under the most favourable conditions as regards the inclination of the face of the target to the trajectory of the shot, they would certainly do no material damage at 2000 yds., or even at the shortest range of 1000 yds.*

An experimental gun has, however, been constructed sufficiently powerful to penetrate this target at a range of 200 yds., namely, a wrought-iron gun made on the new principle of construction and fired with a spherical cast-iron shot, weighing 150 lbs.

This being an accomplished fact, and as there is little reason to doubt that safe guns of this description can be supplied to our fortresses and ships, and that they can be conveniently worked, if suitable arrangements are provided, we may fairly assume that the forts in question will be armed with ordnance equally powerful. It only remains, therefore, to be determined whether the projectile from this gun would penetrate the sides of the enemy's ship at a range of from 1000 to 2000 yds.

Although the present state of the science of gunnery will not admit of an absolute solution of the problem as to the loss of velocity sustained by a projectile in passing through a given distance, still we have a sufficient knowledge of the subject to enable us to determine the point in question, namely, whether the shot will have sufficient power to penetrate.

The following table will shew, near enough for practical purposes, the loss of velocity due to the resistance of the air upon the 150 lbs. spherical shot fired with 40 lbs. and 50 lbs. of powder while passing through spaces corresponding to ranges of 200 yds. 1000 yds. and 2000 yds.—from which it appears that the striking velocity at the shortest range namely 1000 yds. would be about 1160 ft. per second. Now as the 150 lbs. shot, when fired with a charge of 40 lbs. of powder and striking with a velocity of about 1580 ft.

* When this was written it was believed that the target had been penetrated by the 150-pr.; it has since been found that the shot from the 150-pr. did not completely penetrate the target, there is no doubt however that this gun is sufficiently powerful to accomplish this at a range not exceeding 200 yds.

per second, failed, under the most favourable conditions, to penetrate the target completely, it is quite clear that at 1000 yds. range when the velocity is reduced to about 1160 ft., and when the shot would, in the majority of cases, strike the side of the ship obliquely, the 150 lbs. shot would fail to penetrate or to do any material damage.

Range.	Weight of shot.	Charge.	Approximate velocity.	Approximate loss of velocity.	Approximate momentum.	Approximate "stored-up work," or one half *vis viva*.
	lbs.	lbs.				
At muzzle	150	50	1,766·4*		265,000	7,318,000
		40	1,726·4*		259,000	6,993,000
200 yds	150	50	1,621	145	243,000	6,159,000
		40	1,585	141	238,000	5,889,000
1000 yds ...	150	50	1,166	600	175,000	3,186,000
		40	1,141	585	171,000	3,053,000
2000 yds ...	150	50	800	966	120,000	1,502,000
		40	786	940	118,000	1,446,000

There are some persons, I am aware, who take it for granted that guns sufficiently powerful to destroy ships of war at 2000 yds. can be readily made and advantageously employed in land batteries.

This, however, is a mere assumption, and considering all the circumstances of the case, it would appear to be a most unusual and unwise mode of proceeding to incur an enormous expense in providing batteries for these imaginary guns. When these sanguine expectations have been fully realised, it will surely then be time to consider in what positions these extraordinary guns can be most advantageously placed.

It will be interesting perhaps to notice, while upon this part of the subject, what probable effect the experimental gun lately tried with the 150 lbs. shot will have at ranges of 2000 and 1000 yds., when the contemplated change has been effected of making it into a 300-pr. rifle gun.† If we assume that the 300 lbs. shot can be safely fired with a sufficient charge to produce an initial velocity of 1300 ft. per second at a range of 1000 yds., the remaining velocity will be about 1050 ft. per second, taking the most favourable view of the case with respect to the resistance of the air. Now with this velocity the "stored-up work," or half "*vis viva*," in the shot will be represented by the number 5,201,000, and as the "stored-up work" in the 150 lbs. shot which failed to penetrate was about equal to 5,889,000 it is clear that the 300 lbs. rifle shot, even if fired under conditions such as to cause an enormous strain upon the gun, will fail to penetrate at the shortest range

* Initial velocities, as obtained by O. S. Committee, with Navez's apparatus.

† The momentum of the 300 lbs. shot, having an initial velocity of 1300 ft. per second, will be 390,000; the momentum of the 150 lbs. shot when fired with a charge of 50 lbs. was about 265,000; and, as momentum may be taken as a standard of comparison, in relation to recoil and strain, when firing different weights of shot, it is clear that the strain on the gun, when fired under conditions to give a momentum of 390,000 with a 300 lbs. shot, would be enormous.

under the most favourable circumstances as regards direction; surely no further argument is required to prove that the fortifications at Portsmouth, including the two Spithead forts in progress of construction, would entirely fail to prevent the bombardment of the dockyard and storehouses, under present conditions, as regards artillery; and that we have no reasonable grounds for assuming that they will ever be found to offer advantages in any degree commensurate with the cost of their construction, armament, and maintenance.

It only remains, now, to be considered what advantage would be gained by substituting moveable floating batteries for the permanent forts.

In the first place, it may be fairly assumed that a floating battery, constructed specially for harbour defence, and intended, at all times, to be within the immediate vicinity of the base of operations, would possess advantages, both as regards offence and defence, over the enemy's vessels constructed for the object of bombardment, and which are necessarily required to act at a considerable distance from their base of operations, and that consequently in an engagement with these vessels we should have a decided superiority.

As regards the armament of our floating batteries it is remarkable that, in the general discussion which has lately taken place on this subject, it has been asserted, that safe guns capable of penetrating the sides of iron-clad ships at a range of 2000 yds. can be made, and conveniently worked in *land* batteries—but that ordnance sufficiently powerful to act effectually against ships of war, constructed on the new principle, cannot be carried and properly served in a *floating* battery.

It appears to me, however, that it will be found far easier to construct a floating battery to carry the gun, than to make a gun capable of producing an effect so much beyond what has yet been accomplished.

However, no one, I think, will question the possibility of constructing vessels for harbour defence capable of carrying and working a 150-pr. smooth-bore gun, firing a spherical projectile with a charge sufficient to produce the desired results, as regards penetration, at ranges not exceeding 200 yds.

It may be fairly assumed, therefore, that the floating batteries provided for the defence of Portsmouth against bombardment, will be armed with guns of this power. Under these conditions, then, in what respects will the floating batteries have an advantage over the permanent forts in resisting the operations of the attacking force.

It has already been shewn that the existing forts as well as those in course of construction at Portsmouth, would, as a rule, fail to strike the enemy's mortar vessels and gun boats, owing to the unfavourable conditions as regards range and the constant movements of the objects fired at; and that even upon the assumption of the shot having sufficient striking velocity to penetrate, the destruction of the dockyard might be accomplished before the fire of the enemy could be silenced. Moreover, that the forts, if armed with the most powerful guns yet produced, would be unable, even at the shortest range at which the enemy would be exposed to their fire, to do any material damage, from the want of sufficient velocity in the shot to penetrate the ship's armour.

We will now consider how the case stands with floating batteries, in respect to these particular points.

First, as regards the probability of striking the enemy's ships. Upon this there can be, we imagine, but little difference of opinion; for although a gun on an immoveable platform will have a considerable advantage, as regards the degree of certainty of striking the object fired at, over a similar gun on board ship, when the range exceeds a few hundred yards, still, if the latter can be brought within 200 yds. of the object, whilst the operations of the former must be carried on against a moveable object at ranges varying from 1000 yds. to 2000 yds., the ship gun cannot fail to have a very decided superiority over the gun in battery.

Secondly, as to the effect of the striking shot, no one can question the superiority of the moveable floating battery in respect to this particular; for in the case of the forts the effect would be comparatively *nil*, but with the floating batteries every shot could be made to penetrate.

It has already been noticed that our floating batteries would have a superiority, both as regards offence and defence, over the enemy's mortar vessels and gun boats. As this, I believe, will be generally admitted, it would perhaps be superfluous to enter into details. However, there is one particular connected with this point which deserves special notice; namely, that while our ships need only be furnished with the means of resisting the attack, the enemy would have to make provision for the *materiél* to effect the special object in view, that is, the bombardment—and, in addition, must be provided with the means of opposing the force that will be brought against them.

It would appear, therefore, that moveable floating batteries would have immeasurable advantages over permanent forts in resisting a bombardment of Portsmouth dockyard; and, also, that these moveable batteries would be able effectually to oppose an enemy in any attempt of this sort.

It is true that the Royal Commissioners in their report recommend moveable floating batteries but only upon the following grounds :—" Because they would be in some instances most serviceable as auxiliaries to the permanent fortifications for the defence of harbours and inner waters;" and, " because, that such vessels would be of great value during an attack, from their capability of moving to the assistance of any of the forts requiring support;" so that, according to the Commissioners' views, it would be necessary for the enemy to silence the fire of the forts before they could effect their object as regards the bombardment; but, if what has been stated is correct, the enemy need not attack the forts at all, as they would be powerless to interrupt their operations in any material degree.

I will now briefly notice one or two of the chief arguments which have been lately brought forward by the advocates of permanent forts, in support of their views.

It has been said that the forts at Portsmouth will materially assist the floating batteries in their operations against the enemy, and that the two Spithead forts in particular would be able to take the enemy in reverse, while our ships were engaging them on the other side.

Under some circumstances, no doubt, permanent forts might be able to render valuable assistance to a naval force. In the particular case before us, however, the conditions are not, in my opinion, such as to warrant *any* reliance being placed upon them in the way of assisting the floating batteries, and in respect to " taking the enemy's ships in reverse," if we consider the

relative positions of our ships and those of the enemy when engaged, it is evident that the fire from the forts would be as likely, or nearly so, to injure the one ship as the other.

Some there are who advocate fortifications generally—upon the ground, first, of their permanent character; and, secondly, "because of their being less liable to fluctuations than almost any other elements of defence." It must be admitted, however, that, if a fortification fails to attain the object for which it was designed, its permanency becomes a positive evil, as its existence under these circumstances cannot fail, in a country like this, to act most prejudiciously, either by inducing a false security, or in weakening the hands of government, in providing what is really necessary for the safety of the country.

And, as regards "fortifications being less liable to fluctuation than almost any other element of defence," although this may be so, still the altered conditions in relation to the protection of ships have practically rendered the great majority of permanent works now in existence, as well as those in process of construction, comparatively valueless, so far as concerns the objects for which they were designed; for what has been stated about the Portsmouth forts applies with nearly as much, and in some greater, force to the arrangements proposed by the Royal Commissioners for the defence of the country.

As regards the fortifications at Plymouth, for instance, the conditions are nearly the same as those which appertain to Portsmouth—the only difference being, that the enemy's ships would be exposed to the artillery fire from the forts at a range of about 1400 to 1500 yds. instead of, as at Portsmouth, 2000 yds.—a difference, which practically, would be of little consequence. Even in the Medway the proposed forts would be of little avail in preventing the enemy's iron-clad ships from destroying the dockyards at Sheerness and Chatham.

In relation to those works which have been recommended, as a protection against bombardment by an enemy from the land side, it appears to me that, since the adoption of the new system of protecting ships from artillery fire, the landing of an enemy on our coasts may be reasonably considered as an event, so unlikely to occur, as to render it entirely unnecessary to provide for a defence on the land side—for if we were provided with iron-clad vessels of great speed, surely no enemy would attempt, to convey a large force in unprotected transports, and then to land them in open boats, when opposed even by a small number of iron-clad vessels; for although the enemy might be provided with a large protecting force of iron-clad ships, these could not interfere in a way to prevent the destruction of the transports and boats, provided our ships have such facilities of motion as would appear to be attainable in a class of vessel specially constructed for this purpose.

In conclusion, I would observe, that although I entertain a most decided opinion as to the uselessness of the arrangement lately proposed for the defence of the country by land forts, I nevertheless believe that any attempt made by a ship to silence the fire of a fort would completely fail, provided both were on an equality as regards the special advantages which naturally belong to each; and consequently—if in any particular case an enemy's ship cannot attain its object until it has silenced the fire of a fort, then, in such a case, a permanent fort should, no doubt, be resorted to, in preference to a floating battery, as a means of defence.

ACCOUNT

OF

EXPERIMENTS CARRIED ON AT SHOEBURYNESS, ON THE 26TH JUNE, 1862.

[CONTRIBUTED BY CAPTAIN E. J. BRUCE, R.A.]*

THE experiments consisted of cast-iron, wrought-iron, and steel shot fired from the 12-pr.† and 40-pr. Armstrong guns, with service charges, at ranges 200, 400, and 600 yds., against iron plates of different thicknesses. Certain shots were also fired against Mr Scott Russell's and Mr Samuda's targets from the 40-pr., 100-pr., and 150-pr. Armstrong guns, the latter at 200 yds.; the 40-pr. at 600 yds., the 110-pr. at 200, 400, and 600 yds.

The iron-plates fired at were of the following dimensions :—

A. 4 ft. 6 in. × 2′ 6″ × 2″. (Inferior iron, badly rolled plate).
B. 5′ × 3′ × 2″·35.
C. 5′ 5″ × 3′ × 3″. (Not a good plate, badly rolled).
D. 6′ × 3′ × 4″·5.

The plates rested against strong upright timbers, with sloping supports to the rear. Four powerful nuts, bolted through to the upright timbers, overlapped the edge of each plate. The plates were without backing of any kind.

Service charges for the respective guns were used throughout the practice. The 150-pr. was fired with $2A_4$ powder.

Nature of target.	Nature of ordnance.	No. of round.	Projectile. Nature.	Weight.	Length.	Form.	Charge in lbs.	Range in yds.	Elevation.	Deflection.	Indent.	Remarks.
				lbs. oz.	in.				° ′			
A 2″	12-pr	1	C.I.‡	11 9	7	service	1·5	200	nil	10 R	...	Ragged hole through plate 2″·3 × 2″·5. Diameter at back 5″·5; large crack 6″ long in front below hole. Bend of plate 1″·8 in length of 13″. Shot broke up small.
„	„	2	steel	13 2	6·5	„	„	„	„	„	...	Clean hole through, diameter 3″·8 × 3″·6. No bend in plate; hole clean through. Shot broke up in large pieces.
B 2″·35	„	3	C. I.	11 9	7	„	„	„	„	„	″·55	Hit. Indent ″·55 in length of 6″. A four starred crack at the back.
„	„	4	steel	13 2	6·5	„	„	„	„	„	...	Ricocheted and hit low broadside. Shot broke up.
„	„	5	W. I.	12 9	6·5	flat headed	„	„	0 3	„	″·875	Indent ″·875 in length of 11″. Back starred with cracks, and piece in centre of star cracked round.
C 3″	40-pr	6	C. I.	41 8	10·25	„	5	„	0 10	„	...	Hole through, diameter in front 5″·6; at back 11″. Bulge of plate ″·45 in 1 ft. 7 in. Doubtful whether this shot did not hit on old bolt-hole.

* For several particulars I am indebted to Captain Alderson, R.A.

† 12-pr. not beyond 400 yds. ‡ C. I. denotes *cast-iron*, W. I. *wrought-iron*.

Nature of target.	Nature of ordnance.	No. of round.	Projectile. Nature.	Weight.	Length.	Form.	Charge in lbs.	Range in yds.	Elevation.	Deflection.	Indent.	Remarks.
				lbs. oz.	in.				° ′			
D 4″5 Mr Scott Russel's.*	40-pr.	7	C.I.	41 8	10·25	service	5	200	0 10	7 R	1″·6	Struck above a bolt-hole. Indent 1″·6 in 1 ft. 6 in. At back slightly bulged and three cracks.
	„	8	steel	45 4	„	round headed	„	„	0 13	10 R	...	Struck top to the right near last shot; broke off corner of plate.
	150-pr. smooth-bore.	9	W. I.	162 8	10·372	„	50 ($2A_4$)	„	nil	nil	...	Hit target 3 ft. 1″ from right, and 6″ from top of lower plate. Hole through 12″·75 in diameter, and plate broken away to the extent of 4 ft. 2″·75 × 2 ft. 7″·5. A crack 1″ wide from top to bottom of plate; also a crack from a bolt-hole 1 ft. 8″ from point struck; 2 ft. of the rivet (or uniting railway iron) broken off. The plate above the one struck cracked right through.

At the back, one vertical rib broken through; pieces of skin driven into wooden hulk 38″ to the rear; horizontal "stringer" also bent out 1″·1 and cracked through.

The shot fell back five yards from target. The "work done" upon the shot itself was considerable. The sphere was altered in figure so that the front and hind hemispheres were *flattened* (so to speak) and "set up" together, forming a sharp circular flange or rim.

Diameter of shot before firing 10″·372.		Weight of shot before firing, 162 lbs. 3 oz.
Major .... after............12″·969.		do after do 161 lbs. 12 oz.
Minor............... „ .... 8″·2.		

The shock of this blow was transmitted to a heavy structure of timber in rear of target, of 16 paces in depth so as to move the whole mass about ¼ of an inch, as shewn by the displacement of the surrounding sand.

* Mr Scott Russell's target (29′ 10″ × 9′ 9″) was composed of four rows of plates, of the following widths, viz:—

Upper row, 1′ 10⅜″; second row, 1′ 9⅞″; third row, 1′ 8¾″; and bottom row, 2′ 10½″.

The plates (all of hammered iron), 4⅜ ins. thick, were supplied by the Admiralty, and had originally been made for the *Warrior* by the Thames Iron Company.

The total thickness of the target was 8⅛ ins., made up as follows:—a 4⅜ths inch plate, a filling-in piece of 1 in., two 1 in. plates for backing, and two ⅜ in. plates forming the skin.

The construction of the target at the rear consisted of two longitudinal stringers, 5·5″ deep, one above and the other below the port; also two iron waterways representing the upper and main decks. The vertical ribs were 10·5″ deep and 21·25″ apart; and in order to represent the mode of construction with iron backing as proposed by Mr Scott Russell, a lining of iron ½″ thick was placed on the upper part of the target (instead of the 3″ of teak lining of the *Warrior* target), the remainder of the target being left open in order to allow of the examination of the skin.

The object of the original experiment was to test Mr Scott Russell's system of continuous riveting, combined with iron backing instead of wood.

Projecting riveting was used on one half the target, and flush riveting on the other half. There were neither bolts nor rivets in any of the armour plates, with the exception of the bottom one on the right side of the target, which had four rivets through its centre.

The target had two port-holes in it.

Nature of target.	Nature of ordnance.	No. of round.	Projectile. Nature.	Projectile. Weight.	Projectile. Length.	Projectile. Form.	Charge in lbs.	Range in yds.	Elevation.	Deflection.	Indent.	Remarks.
				lbs. oz.	in.				° ′			
C 3″	40-pr.	10	steel	45 4	10·25	round headed	5	200	0 10	5 R	nil	Hole clean through; diameter in front 5″×5″·5; at back (inner) 5″·5, (outer) 10″. No indent, but clean punch through, without any curvature of plate.
„	„	11	W.I.	43 0	9·25	flat headed	„	„	„	„	5″·75	Bulge of plate extending over a surface 2ft.5″ × 3ft. Indent 5″·75. Four cracks about 1″ wide starring from centre of blow. Bulge at back extending over a space 1 ft. 7″ × 1 ft. 6″; plate opened out in wide rent. Four great cracks.
												Much more damage from wrought-iron shot, more injury to plate on the whole, though the steel shot punches a fair hole clean through. Shot set up 1″·75 by force of blow.
C 3″	„	12	C.I.	41 8	10·25	service	5	„	„	5 R	8″·5	Indent 8″·5 in length of 1 ft. 8″, diameter of hole 6″. Struck on margin of No. 10. Ragged irregular hole at back.
B 2″·35	12-pr.	13	„	11 9	7	„	1·8	400	0 30	12 R	·7″	Hit centre of plate nearly; slight indent ·″7. No bend of plate, very slight star of three branches at back. Indent 1″·05 in 1 ft. 2″.
„	„	14	W.I.	12 9	6·5	flat headed	„	„	0 32	10 R	1″·05	Effect more of a *bend* in the whole plate. Bulge and seven-starred cracks at the back. More "work done" still with the wrought-iron. Shot itself "set up" 1″·5.
„	„	15	„	„	„	„	„	„	0 33	18 R	...	*Missed.
D 4″·5	40-pr.	16	C.I.	41 8	10·25	service	5	„	0 38	10 R	...	Missed.
„	„	17	„	„	„	„	„	„	0 35	3 R	...	Indent ″·625; diameter 3″·1. No breaking of plate. Back, slight crack from bolt-hole.
„	„	18	steel	„	9·25	flat headed	„	„	0 38	9 R	...	*Missed.
„	„	19	„	„	„	„	„	„	0 39	1 R	...	*Missed.
„	„	20	„	45 4	10·25	round headed	„	„	0 35	3 R	1·85	Indent 1″·85; diameter 5″·5. No bend in plate. Back, crack 1 ft. 8″ laterally, opening of crack ·″65; two small upward cracks from it. Shot broke up.
„	„	21	W.I.	43 0	9·25	flat headed	„	„	0 38	„	1″·15	Indent 1″·15 in 1 ft. 6″·5; diameter 4″·2. A certain amount of work lost in knocking down the plate from its fixtures, accounting for small effect. Bulge at back, and four starred cracks, one of them 1ft. 10″ in length, gaping ⅜ of an inch in widest part.
† Mr Samuda's target.												
	„	22	steel	45 4	10·25	round headed	„	600	1 0	4 R	2″·2	Indent 2″·2; area of indent 7″·7 × 5″·8. Struck on junction of two plates.
	„	23	C.I.	41 8	„	service	„	„	1 3	8 R	·65	Indent ″·65, diameter 3″·

† Mr Samuda's target (20 × 10 ft.) was composed of two plates 20′ × 3′4″ × 5″, and two centre plates, the one to the left of the port-hole being 11′6″ × 3′4″ × 5″, and the one to the right of the port-hole, 6′8″ × 3′4″ × 5″. The skin was 1 in. thick, and longitudinal ribs 2½ ins. thick were placed at the junction of the plates, by which means the whole target was supposed to be of uniform strength. The upper and lower plates were secured by bolts 14 ins. apart, and the middle plates by alternate bolts and rivets. A thin layer of india-rubber was placed between the armour plate and skin, and leather under the bolt-heads.

The target was supported by a framework of 14-in. timbers 3′ 6″ apart, strutted to the rear, the feet of the struts being secured to timber piles.

The total weight of the target (exclusive of the beams of the ship) was 27 tons 19 cwt.

The armour plates were rolled by Messrs John Brown and Co. of Sheffield.

* Flat-headed projectiles gave very uncertain practice.

Nature of target.	Nature of ordnance.	No. of round.	Projectile. Nature.	Weight.	Length.	Form.	Charge in lbs.	Range in yds.	Elevation.	Deflection.	Indent.	Remarks.
				lbs. oz.	in.				° '			
*	40-pr.	24	steel	45 4	10·25	round headed	5	600	1 3	12 R	2''·45	Indent 2''·45; diameter 5''·55. Worked up the rim of plate at top of target half an inch.
*	„	25	wrought iron	43 0	9·25	flat headed	„	„	„	„	''·65	Indent ''·65; diameter 3''·9 × 4''·8.
†	110-pr	26	cast iron	110 8	12·25	service	14	200	0 24	10 R	2''·15	Struck at the bottom of the 2nd plate from the top, grazing the lower riveting. A semi-circular crack extended for an area of 12'' × 22''. The plate was driven ·7'' in a length of 1 ft. 8''. Diameter of indent 6''·5. At the back, one rib with its angle-iron was cracked in two places, and a through bolt (not covered by armour plate) was broken.
†	„	27	wrought iron	116 8	11·25	flat headed	„	„	„	12 R	2''·3 ...	Hit the third plate 5·''5 from the top. A crack extended from the bulge nearly to the bottom of the plate. Indent 5''·7 × 6''·6. The riveting was cracked across in two places and forced up for a length of 2 ft. 6'', and the plate was driven in 1''. At the back a rib was broken, and the one referred to last round was broken in a fresh place. The skin was broken for a short distance and a joint strip was forced out. The shot set up 3''·25.
†	„	28	cast iron	110 8	12·25	service	„	400	0 42	8 R		Missed.
†	„	29	„	„	„	„	„	„	„	10 R	1''·7	Hit the lower plate 1ft. from the top. The riveting started ½'' in a length of 3 ft. and cracked along its centre for a length of 2'·7''. The plate was cracked at the back through half its thickness, as seen at the outer end. At the back, one of the ribs was broken from its outer rivet-hole to the outside, and two angle-irons were cracked. The skin slightly bulged out.
†	„	30	wrought iron	117 1	11·25	flat headed	„	„	0 44	13 R	2''· ...	Struck on the projecting riveting between the lower and third plates. The riveting was cracked across in two places and compressed at point of impact. A semi-circular crack at a distance of 1ft. from point of impact. At the back, a rib and two angle-irons cracked through, one rivet in angle-iron broken, and skin cracked across from rib to rib. Shot broke up into several pieces.
†	„	31	cast iron	110 8	12·25	service	„	600	1 6	8 R		Missed.
†	110-pr	32	„	„	10·25	„	„	„	1 12	„	1''·65	A crack 1 ft. long from the point of impact, 1 ft. of the riveting under the bulge damaged, 2''·5 being broken off. The riveting was cracked across at 2 ft. from front of impact. At the back, one rib and angle-iron cracked and the skin slightly bulged.
†	„	33	wrought iron	117 11	11·25	flat headed	„	„	1 13	12 R	2''	Hit the broken plate, a crack 15'' long at 13'' from point of impact, also another crack from a bolt-hole to the top of the plate at a point 2 ft. 1''·5 from impact. At the back, two rivets of the lower stringer were broken, an angle-iron and rib broken, and the skin cracked round a rivet hole. Shot set up 3''·75.

* Mr Samuda's target. † Mr Scott Russell's.

ACCOUNT

OF

EXPERIMENT CARRIED ON AT SHOEBURYNESS, ON THE 7TH JULY, 1862, TO DETERMINE THE RESISTING POWERS OF THE "MINOTAUR" CLASS OF MEN-OF-WAR.

[CONTRIBUTED BY CAPTAIN E. J. BRUCE, R.A.]

THE target consisted of three plates.

The top one (12′ 6″ × 3′ 4″ × 5·5″) was made by Messrs John Brown and Co. of Sheffield.

The centre one (9′ × 3′ 7″ × 5·45″) was made at the Thames Iron Works.

The bottom one (12′6″ × 3′ 4″ × 5·5″) was made by Messrs Beale and Co.

The backing consisted of 9″ of teak, and the same skin as in the *Warrior* target.

Each plate was fastened with three rows of through bolts, the upper and lower rows being 1¾″ diameter, and the centre row 1½″. A strip of iron 1¼″ thick, was placed in rear, at the junction of the plates, the upper strip being 16″ wide, and the bolts passing through it; the lower one was only 10″ wide, and was not bolted through. The support in rear was similar to that of the *Warrior* target.

The range was 200 yds., and the guns used were the 12-ton gun and 68-pr. smooth-bore.

No. of round.	Nature of ordnance.	Projectile.			Charge in lbs.	Elevation.	Deflection.	Indent in ins.	Remarks.
		Nature.	Weight.	Diameter.					
			lbs.	ins.					
1	150-pr	cast-iron shot.	150	10·35	2A, 50	nil.	nil.	nil.	Hit the centre plate 2′ from the bottom, and made a hole through the plate 12·5″ × 12·2″, and about 13″ deep. The plate was driven in 1·1″ at the bottom, and 1·5″ at the top, and buckled forward ·45″ at the end by the port-hole, and ¼″ at the outer end. The lower strip at the junction of the plates also started ·3″ from the backing. Two bolts in the bottom row of the upper plate started ⅛″ and one in the centre row ⅝″. The top and bottom bolt by the port-hole of the centre plate started ·2″, and those in the top row of the lower plate started respec-

No. of round.	Nature of ordnance.	Projectile. Nature.	Weight.	Diameter.	Charge in lbs.	Elevation.	Deflection.	Indent in ins.	Remarks.
	150-pr	cast-iron shot.	lbs. 150	in. 10·35	$2A_4$ 50	nil.	nil.	nil.	tively 1″, ⅝″, and ¼″; also one in the centre row of the same plate ¼″. The shot broke up, and parts of the plate and shot were driven into the wood backing. No cracks on the plate; iron good; at the back, two vertical iron ribs cracked (one on each side of point struck); one of these ribs broken clean in two. Four bolt-heads broken off, two in centre plate, one in lower, below the seat of injury, and one to the right of lower plate, 3′5″ from the point struck; a rivet head gone near same place. Two angle-irons cracked. Iron shelf-piece carried away. Eleven rivet heads broken off. Skin much bulged, and a three-starred crack from the bolt-hole where struck. Serious bulge of skin over a space 1′6″ × 1′6″. General *bend* of inner surface over a space 3′6″ × 3′6″.
2	„	„	„	„	„	„	„	„	Hit the top plate 17″ from the bottom, and made a hole through the target; 13″ × 12·5″ being the diameter in armour plate. One edge of the hole was on a bolt which was driven out, and a crack extended from the bolt-hole parallel to, and 1·3″ from the edge of the shot hole, for a quarter of its circumference. Eight bolts in this plate were now started, viz. three in the upper row, three in the lower, and two in the centre. There were no radiating cracks on the plate, but the quality of the iron was unequal, the exterior of the plate being good, but large crystals visible on the centre. Fracture laminated. The plate buckled ·3″ at its outer end, and the centre plate had now buckled 1″·1 at the end by the port-hole, but was set back into its place at the other end, where it had buckled ¼″ the last round. At the top of the target, 1′ of the backing was forced up 4″·2, and a filling-in piece 1′10″ long was forced up 8″; also a horizontal wooden baulk, 1′7″ to the rear, was quite cracked through. At the back, two bolt-heads broken off in centre plate, one in lower; large irregular hole; skin doubled back; pieces of shot clean through along with teak backing and fragments of plate. Hole and breakage 18″ × 14″. Solid timbers supporting the top of the target in rear (total thickness, 1′8″), cracked and splintered; upright baulks of timber, 4′6″ in rear, penetrated by splinters of iron; bolt-heads and rivet-heads picked up 36′ in rear. Front portion of plate struck (bearing impression of blow), found 15′ in rear of target. Effect partially concealed by the supporting beams at top, which suffered in being rent by blow.
3	„	„	„	„	„	„	„	„	Struck the lower plate 5″ from the top, and made a hole through the target, the diameter in front being 13″. The plate buckled ·5″ at the outer end. Three cracks, each about 2·5″ long from the edge of the hole, one extending to the top of the plate. Two bolts in the centre row had started respec-

No. of round.	Nature of ordnance.	Projectile. Nature.	Weight.	Diameter.	Charge in lbs.	Elevation.	Deflection.	Indent in ins.	Remarks.
			lbs.	in.					
	150-pr.	cast-iron shot	150	10·35	$2A_4$ 50	nil.	nil.	nil.	tively ·8″ and ·9″, and one in the upper row (3′ 4″ from the point of impact) started ½″; also one in the lower row, under the shot-hole, started ·3″. Plate very badly welded, and much laminated. The shot broke up. At the back, large hole, daylight through; vertical rib broken clean through, and bent back 2′ 6″ from target; large portions of skin, bolt-heads and rivets broken away; cone of shot found lying 15′ in rear; other fragments of shot and plate driven through; shreds and splinters of teak backing protruding. The hole and rent, 16″ × 2′ 6″. Entire bulge, 3′ 6″ wide.
4	"	wrought iron.	162	10·364	"	"	"	"	Struck the centre plate 2′ 3″ from the bottom, 1′ 6″ from the right side of the plate, and 3′ 11″ from the hole made by No. 1 shot. The shot remained in the plate. The target was tremendously shaken. The centre plate had now buckled forward 3·3″ at the end by the port-hole, and was driven in 6·5″ at the outer end. The whole of the backing of the target, on the right side, was driven back, the space being 6″ at the top, and 9·25″ at the bottom of the upper plate. The upper plate was unsupported by any—for a length of 6′ from the right side. The teak backing, through which the bolts passed, was cracked quite through. The diameter of the hole made was 13·5″, and the bulge on the plate was 2·5″ in an area of 3′, whereas in No. 1 round the bulge in the plate was only ·5″ in a smaller area. A narrow crack extended from the top of the hole made by No. 1 round to the top of the plate. At the back two vertical ribs and angle-irons broken, one on each side of blow; bolt started and driven out 1′2″; skin two small cracks at bolt-hole; three bolt-heads off; two in centre plate, one in top. Iron shelf-piece loosened and partly bent out. Bulge of plate 4 × 2′. Interior damage less than in No. 1, but distributed over a block of masonry several feet in rear, on which leaned the intervening beams between it and the top of target. The entire breech of the 12-ton gun was blown out at this round, and fell 12 yds. to the rear, rebounding 21 yds. further to the rear, where it remained. A 14″ baulk of timber in front of the platform, to which the tackle for checking recoil was secured, was broken through. In considering the damage done to the target by this round, the accident here recorded must be taken into account, as the loss of *work* must have been considerable.
5	68-pr.	wrought iron.	71	...	W.A. 16	20′	"	2·4	Struck the lower plate 10″ from the bottom, and under the port-hole. Diameter of indent, 9·5″; area of bulge in plate, 19″ × 18″; depth in area, ·5″. One small crack on indent. At the back, one rivet head off. No other damage visible.
6	"	cast iron.	67	...	"	"	"	3·	Struck the lower plate just above the last round. The indent of last round now measures 3·2″, and the diameter of the two indents is 1′3″ × 9″. The area of bulge 21″. No radiating cracks and no damage to the fastenings; but the plate had very slightly started at the top by the port-hole. At the back, no damage visible.

From the results of this experiment it is plain that the powers of resistance of a structure such as the *Warrior* are far superior to those of a vessel constructed on the plan proposed for the *Minotaur*.

The additional inch of iron in the thickness of the plate is clearly no compensation for the reduction of 9 in., or half the thickness of teak backing.

ON THE ADAPTATION OF THE CUPOLA OF CAPTAIN COLES

TO

MODERN FORTRESSES.

By F. DUNCAN, M.A., Lieut. R.A.
FELLOW OF THE GEOLOGICAL SOCIETY.

That a change will of necessity occur in modern warfare, consequent upon the two great discoveries, which occupy public attention at present,—the advantage of iron-platings and the seeming absence of a limit to the increasing power of artillery, has become apparent to the most superficial observer. As yet the attention of scientific men has been devoted almost exclusively to naval changes; but there can be little doubt that an alteration in the modern system of fortification is more or less imminent. It is evident that fortresses derive a higher ratio of benefit from improvements in artillery, when these improvements involve heavier guns and larger charges, than either ships or armies in the field; for they have ampler magazine and other accommodation than any vessel, nor are they limited by considerations of tonnage or capabilities for sailing. And an army in the field cannot exceed a certain limit in the weight of its siege-train *matériel*, and in the reserves of ammunition which accompany it. These are circumstances which have occurred to many in the contest between artillery and ironsides; but it seems (as far as I am aware) to have escaped any writers on the subject, that the improvements in artillery will not be more advantageous to forts than might the adaptation of the cupola and other instruments become, which are considered to belong exclusively to vessels.

A few suggestions on the advantages which the introduction of this invention of Captain Coles into our fortifications would secure, may not be superfluous at the present crisis. These may be briefly enumerated as

(1) Command given to the fort;

(2) Immense lateral range;

(3) The power of bringing every gun in the work to bear upon any single point, even if that point were in the work itself; thus enabling the defenders to subject the assailants to a murderous fire even after they might have entered the fort;

(4) Economy of numbers at each gun;

(5) The power of doing away with outworks, and the increased accommodation for troops;

(6) Economy in construction;

(7) Durability and invulnerability.

The first three of these are due to the same cause. A gun in a cupola may be considered a gun *en barbette;* for the cupola could be placed on a level with the crest of the work, and would therefore give increased command to the gun it covers, and also an unlimited lateral range. At present a gun *en barbette* is an object for the enemy's artillery, and exposes its detachment to their riflemen. They are therefore only placed as a rule in the salients of the work; and the rest of the guns are cramped by the contracting influence of their embrasures, than which nothing more effectually limits their fire and utility. The sole of the embrasure checks the depression of the piece after a certain limit; and the sides reduce their lateral range to a comparatively small angle. Even the guns in the salients can only be traversed over a limited arc of the circle; whereas the revolving cupola would move completely round, and might allow of the greatest depression. It would thus command the whole surrounding country, and might be turned so as to give a species of reverse fire upon any point within, which might be in the possession of the enemy.

The gun detachment would be safe and completely invisible; and this suggests the 4th of the advantages enumerated,—economy of numbers to work each gun. The large number we would allow at present to each gun during a siege is calculated to allow for casualties. Where the risk of casualties is so immensely diminished, the allowance to be made becomes proportionably less; and the guns will be worked easily with diminished numbers.

Our next advantage, in order, is the power of doing away with outworks. These, such as ravelins, &c. are meant to throw a fire which would sweep that part of the glacis in front of the faces of the bastions which could not be covered by the fire from the work; and in general terms to compensate for the want of lateral range in the guns of the fortress. But where the guns of the work can be concentrated upon any spot, and no part of the surrounding country but can be brought under their fire, a ravelin becomes quite unnecessary. A cupola in each salient would act better than any ravelin; and their guns could be easily made to command even the ditch in front of the curtain, and throw showers of case-shot upon the heads of any storming party. The second clause of the 5th head is a *sequitur* to the first. Given a certain space of ground on which to build a work, that work which consumes most of that space in outworks like ravelins has the least accommodation for troops, for in calculating the number of men to fill a work, we would be reluctant to take into consideration anything save the main work.

The economy of construction which we have included in the list of advantageous consequences on the adoption of this invention is partly the economy which follows a judicious outlay. In the first place, a fort whose guns are under cupolas, requires no traverses to resist enfilade and ricochet fire. Every cupola is a traverse to the next; and we are thus spared first the expense of constructing earthen traverses, and secondly, that of keeping them in repair,—an item of some importance in severe climates like our American colonies, where the frost tears up earthenworks more effectually than the most powerful shells. By this system, also, the interior of the parapet with its banquette, embrasures, revetments, &c. is avoided; and the cupolas could be placed on the crest of the superior slope, the earth sloping back

towards the *terrepleine* at its natural inclination. In this way, a work could be built infinitely more quickly, more simply, and more economically than at present. By increasing the lateral range of our guns, we do away with the necessity of having so many as we have in our modern fortresses to cover every point of the surrounding country by which the enemy might approach; and this dimunition of the armament would compensate for the additional expense of the cupola.

Some of our fortresses have cavaliers with guns on the top. Let these be placed under cupolas, and two would be as efficient as ten are at present.

Our last mentioned advantages "durability and invulnerability" apply more to the armament than to the work. The invulnerability of the cupola has been ably insisted on by its talented inventor, and proved by experiments; and the durability which the gun and carriage would attain from their shelter from the weather would be very great. The constantly recurring expense of lacquering guns and carriages would be greatly avoided; and in a kingdom whose forts are so numerous, even this consideration is one not to be despised.

But if in regular fortifications the cupola could be introduced with advantage; how much more would this be the case in such works as our Martello towers. By a judicious arrangement, these towers might attain a dignity in fortification little dreamt of. Let the cupola be placed on the top of, and coinciding with the circumference of, the tower; surround it by a deep ditch, and throw the whole of the earth excavated from it so as to form a steep glacis round the tower, whose slope if possible should be a prolongation of the angle of the cupola itself, and we have at once a circular fort of singular strength and simplicity. A line of such towers along a coast or round a harbour, each perfectly self-acting, would form a serious obstacle to an invading force. And in a country with so large a coast line, as Great Britain, these might be found at once an economical and an efficient means of connecting our larger works, and so keeping up a continuous and formidable line of resistance.

BELGIAN EXPERIMENTS

ON THE

PROOF OF GUNPOWDER IN 1858.

Arrangements have been recently made by directions of the Secretary of State for War for the future testing of all gunpowders by ascertaining the initial velocity of shot from a standard gun with a uniform charge. These experiments will be made at Shoeburyness, under the direction of the Ordnance Select Committee, with Navez electro-ballistic apparatus: using a smooth-bored service 32-pr. for ordinary LG powder, and probably a 40-pr. rifled gun for rifle large grained LCR or A_4 powder; in addition to the standard 12-pr. Armstrong gun which has been used for the same purpose for the last twelvemonth.

The following extracts from a Report by Lieut.-Col. Younghusband, R.A., dated Liége, July 15, 1858, contain much useful information bearing on the same subject, and will form an appropriate introduction to it in these "Proceedings."

"I have attended some experiments which have recently been made at Antwerp on the proof of gunpowder. These experiments, as tending to shew the proofs to which gunpowder for cannon ought to be subjected, are of the highest importance and interest, and I think worthy the attention and consideration of officers employed, either in the manufacture of gunpowder, or its use in testing the endurance of cannon.

"I am informed that Colonel ———, the officer in charge of artillery *matériel* at Antwerp, has, for nearly a year past, been engaged, unofficially, in experiments for proving gunpowder, but it is only within a recent period that the Government has ordered their systematic continuance. The circumstances that gave rise to them were, I believe, these:—

"Last year, several iron guns burst in the course of ordinary practice at Brasschaet; a Commission of officers was ordered to investigate the probable causes of these accidents; their general opinion was that all guns received into the service ought to resist a moderate number of rounds with any powder which had passed the regulated tests; but a strong opinion having been expressed by some members of the Commission that some of the powder issued for service was extraordinarily destructive to cannon, the character of which was not exhibited by the regular proofs, the Government ordered experiments on the proving of powder to be made, and likewise others having the twofold object of testing certain mixtures of iron for guns, and their resisting powers to different qualities of powder.

"I am unable at present to state more than the general results, but have been promised a copy of the experiments in detail. I am, however,

of opinion that those relating to the endurance of cannon are not being carried out in this country on a sufficiently extensive scale to yield conclusive results.

"The experiments on the endurance of cannon are now in progress at Brasschaet. Up to the present time they have been confined to firing four 24-pr. iron guns, cast of the same mixture of metal, with two different qualities of powder; one quality passed as a 'quick,' the other as a 'slow' powder. The guns were mounted upon garrison carriages and placed in blindages to avoid accidents and keep together the fragments after bursting. The service charge of 4 kilos. of powder (9 lbs.) and one shot has been employed, and the guns laid point blank.

The first gun, fired with a 'slow' powder, burst at the 63rd round.

The third gun, fired with a 'quick' powder, burst at the 90th round.

"So far, therefore, these experiments have yielded nothing conclusive respecting the powder, but there seems little doubt that the metal was very inferior.

"The experiments relating to the proof of powder have been as follows:—

Samples of powder from different barrels, and various periods of manufacture were taken from the magazine at Antwerp, and thus tested:—

(1) The usual proof. This consists of firing a shell filled with lead weighing 29·3 kilos ($64\frac{2}{3}$ lbs.), from a mortar éprouvette with a charge of 92 grammes ($3\frac{1}{4}$ oz.)

(2) The lead being taken out of the shell, thus reducing its weight to 15·9 kilos. (35 lbs.), the empty shell was fired with a charge of 62 grammes (2·2 oz.)

(3) An empty shell, weight 4·956 kilos. (10·9 lbs.), was fired from an 18-pr. mortar with a charge of 54 grammes (1·9 oz.)

"The following table contains the results:—

Sample of powder.	Range in Mètres.		
	Mortar éprouvette. Solid projectile.	Mortar éprouvette. Hollow projectile.	18-pr. Mortar. Hollow projectile.
1857, (No. 2)	217·2	92·6	56·7
1857, (No. 4)	233·0	127·3	117·3
1852..................	237·3	133·8	113·1
1853..................	237·2	133·6	125·1
1857, (No. 3)	242·5	140·0	120·4
1856..................	236·7	148·6	122·0
1854..................	236·5	149·5	137·8
Reddish, unknown	240·2	157·8	108·6
1855..................	237·2	158·7	129·4
Blue, unknown ...	234·0	175·6	149·2
1850..................	234·3	184·7	157·9
1857, (No. 1)	243·2	189·7	162·3
Blue, unknown ...	235·7	231·1	220·5

"From the above experiments it will be seen,

(1) That the ranges of the solid projectile only varied between 217·2 and 243·2, while those of the hollow projectiles varied from 92·6 to 231·1, and from 56·7 to 220·5.

(2) That, omitting powder 1857 (No. 2), the ranges of the solid projectile were comprised between the limits of 233·0 and 243·2, while those of the hollow projectiles ranged from 127·3 to 231·1 and from 117·3 to 220·5.

(3) That the powders classed themselves in the same order, nearly, with both natures of mortars when hollow projectiles were employed (which may be considered as the order of degrees of quickness), but that the heavy projectiles afforded no such regular indication.

"The next experiment consisted in sifting some powder that had been very long in store, and separating it into five different parcels according to the size of the grains.

The results were :—

Powder. No. of grains in 1 gramme.	Ranges.		Powder. No. of grains in 1 gramme.	Ranges.	
	Mortar éprouvette, solid projectile.	18-pr. mortar, hollow projectile.		Mortar éprouvette, solid projectile.	18-pr. mortar, hollow projectile.
3400	232·2	180·0		*Second experiment.*	
1350	234·2	154·9	1350	232.0	128·4
505	233·2	97·1	518	242·2	112·6
270	234·0	89·5	303	240·2	81·1
106	232·0	85·3	131	238·8	78·5

"From this table it will be seen that the degree of 'quickness' of the powder, as influenced by the size of the grain, is well shewn by the variation in the range of the hollow projectile, while no sensible difference is shewn by the solid projectile.

"An examination has been made of powder manufactured by the *dry* process. It was supposed that, in order to provide against the requirements of a long siege, and avoid the danger of keeping large quantities of powder in store in a fortress, the ingredients only, might be stored and incorporated from time to time, by the *dry* process.

"Powder, so manufactured, though not giving evidence of any unusual properties when fired from the mortar éprouvette, was found exceedingly 'quick' by the hollow projectile and therefore proportionately destructive to cannon.

"When employed for cannon, it has been found by Navez's electro-ballistic apparatus that the 'quick' powder gave no greater initial velocities than 'slow' powders.

"On the contrary, in some cases even lower velocities were obtained. With the musket and spherical ball, the initial velocities were found to be greater or less according as the ranges of the hollow shell increased or diminished.

"It has been known for some time past that the results obtained with the mortar éprouvette do not correspond with those of the cannon in testing the

relative forces of different kinds of powder; indeed, Major Mordecai remarks that the common éprouvettes are of no value as instruments for determining the relative force of different kinds of powder. The experiments in Belgium seem to indicate a method of very satisfactorily classing powders for every service, in the following manner.

"Let the requisite projectile force be determined, and let it be shewn by a *minimum* range of a solid shot from the mortar éprouvette for every sample of powder. The same powder should then be employed to fire a hollow projectile, the range of which must be *below* a certain amount. By means of these experiments a 'slow' powder, or one which exerts a less destructive effect upon a cannon, and at the same time one which gives the required initial velocity (two qualities that are quite consistent with each other), may be obtained. It seems probable, that the lighter the hollow shell, provided of sufficient strength, and the less the windage, the more marked will be the results; perhaps an accurately turned cast-steel shell would be found best suited for the purpose.

"Continuing the same reasoning, the solid shot ought to be as heavy as possible.

"Initial velocities ought to be fixed, and experiments occasionally made to ascertain that the standard has been obtained: Navez's electro-ballistic apparatus is well suited for this purpose.

"It will probably be found especially advantageous to employ a 'slow' powder with rifled guns. As the projectile must follow the grooves, and a comparatively longer time is occupied in its passage up the bore, it may be concluded that the action of the powder ought, in such cases especially, to be gradual, and, as it were, *pushing* rather than sudden and percussive, in order to diminish the destructive effect upon the cannon.

"It is admitted that our present proof for gunpowder affords very imperfect indications of real qualities. Experiments similar to those made in Belgium can very easily be carried out in England, and I beg to recommend the subject to the consideration of the Secretary of State for War."

GUN COTTON.

The following extracts, from the Report of an Austrian military commission on gun cotton, will be found to contain information of some interest, notwithstanding its defective nature; and in the absence of fuller details, which the Committee trust to be able to produce hereafter, will give Officers some idea of the grounds on which so great a military revolution as the partial substitution of this substance for gunpowder, is being worked out in Austria.

J. H. L.

DURING the autumn of 1861, the ministry of war (*Kriegs-Ministerium*) at Vienna, have appointed a commission to inquire into the merits of the new explosive material, and to give an opinion on the subject.

The conspicuous and striking advantages, which this new chymical product attested, may be regarded as the motive of this measure taken by the War Department of Austria.

It is however to be remarked, that in consequence of peculiar circumstances, not to be entered upon at present, all the members of the said commission have been well known to be adverse to the new material, at least up to that time.

Notwithstanding this circumstance, the said commissioners have, after a most thorough test based exclusively on actual experiments on a grand scale, given a Report to the following effect:—

1. By equal effects in heavy ordnance and small guns, the weight of new material to the weight of gunpowder is in proportion of 1 to 3.

2. The effect of the new material is far more constant (*bedeutend gleichmässiger*) than that of gunpowder; it must be acknowledged that the first named preparative by ensuring a higher precision of aim, is considerably superior to the second (*ein wesentlicher Vorzug*).

3. The new explosive material made in former times, and since duly preserved, shows, after the lapse of some considerable time, no alteration prejudicial to the effect and qualities of the said preparative.

4. The destroying influence (*Einwirkung*) of the new material on the barrel of bronze and other guns is entirely obviated (*aufgehoben*) by the new material, according to the official trials of 1860.—"As a proof of the above I quote the fact, that after more than 2000—say two thousand rounds fired from a bronze 4-pr. in the shortest possible interval, the gun has not suffered any damage whatever of its first effective qualities (*Leistungsfähigkeit*). The new material may also be employed with cast-iron breech-loading guns, &c. with the same success."

5. The method of producing the new material combines all the conditions which lead us (the commissioners) to the conclusion, that the production of the preparative of a constant effect (*gleichmässig wirkend*), and also its invariableness, are bound within rather wide limits. The necessary apparatus for the manufacture of this new material is simple and not expensive, facilitates and accelerates the manipulation, which moreover is of a far less dangerous character than the manufacture of gunpowder. "During the summer of 1861 there have been produced about 50 tons of this new material without having been attended by the slightest accident."

6. The manufacture of all kind of cartridges for guns and for mines is very simple (*sehr einfach*), easily and rapidly to be effected (*leicht und rasch bewirken*), on account of the exclusive employment of machines, whilst it is well known that with the manufacture of gunpowder cartridges, hand labour is predominant.

7. The conveyance of this material to the most distant parts of the empire—with railway and common carriage—under intentionally difficult circumstances, has always been effected without delay or trouble whatever (*umstandlos*).

8. This new material after burning, leaves only an extraordinary small quantity of deposit (*nur äusserst geringe Rückstände*). The barrel of a gun, after many rounds is scarcely blackened (*nach vielen schüssen kaum geschwärzt*), and the disagreeable smoke attending the explosion of a gunpowder cartridge is done away altogether (*fällt ganzweg.*)

9. The new explosive material submerged under water six to eight weeks showed no alteration whatever of its previous effective qualities (*keinerlei Veränderungen ihrer ursprünglichen Wirkungsfähigkeit*) after being dried by means of machines in a few minutes.

10. The effect of recoil (*Rückstoss*) is by employment of this new material far less (*bedeutend geringer*) than by the employment of powder cartridges.

11. If we consider the quantities of gunpowder and this material to produce the same effect, there is then at present no difference of note between the cost of both preparations; if however the manufacture of this

material will be practised on a grand scale with machines, then its manufacture promises considerable economical advantages in favour of this new material. It remains further to be mentioned that the small specific weight of this material, and thereby the smaller expenses of conveyance, as well as the possibility of employing lighter guns by these cartridges, will cause savings which are not to be overlooked.

"In consideration of the above report His Majesty the Emperor of Austria commanded the immediate and exclusive introduction of this new explosive material for the ordnance and smaller guns of the whole Austrian army and navy."

REPORT

ON

EXPERIMENTS WITH NAVEZ'S ELECTRO-BALLISTIC APPARATUS.

By CAPTAIN NOBLE, late Royal Artillery.

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1. In forwarding to the Ordnance Select Committee the results of the experiments in initial velocity, which I have had the honour of carrying on under their direction, I have to make the following remarks :—

2. The instrument employed in these investigations was the electro-ballistic apparatus of Major Navez,* and it may not be out of place here to recapitulate the leading points of its construction.

The apparatus itself is merely an arrangement for measuring, with extreme accuracy, a certain very small interval of time. Two screens, the nearer one a short space from the muzzle of the gun, are placed at an accurately measured distance apart, and it is the object of the instrument to ascertain the time which the projectile takes to pass over this measured space.

3. The apparatus consists of three parts, the pendulum, &c., the conjunctor, and the disjunctor. The principal part is the pendulum and graduated arc. The pendulum, before an observation, is held suspended by an electro-magnet, the current magnetising which passes through the first screen. To the pendulum is attached, by means of the pressure of a spring, an arm with a vernier. The pressure of this spring is so regulated that the arm vibrates freely with the pendulum, but at the same time it offers but little resistance to the action of a powerful horse-shoe electro-magnet, which, when the circuit magnetising it is complete, clamps the vernier arm with great firmness.

4. The current which passes through the second screen holds, by means of an electro magnet, a weight suspended over a spring, a point from which is kept just over a cup of mercury. When this weight is permitted to fall, it presses the point into the cup of mercury, and completes the circuit, magnetising the horse-shoe magnet which clamps the vernier needle. This part of the apparatus is termed the conjunctor. The action of the instrument is very simple and readily understood. When the projectile cuts the wires in the first screen, the magnet which holds the bob of the pendulum in its initial position is demagnetized, and the pendulum commences an oscillation. When the wires in the second screen are cut, the weight of the conjunctor drops, completes the circuit, clamping the vernier, and the arc through which the pendulum has moved is a datum from which may be computed the corresponding time.

5. An important part of the apparatus (the disjunctor) remains yet to be mentioned. It will be obvious that the arc which we have just supposed to be measured corresponds to the time which the projectile takes to pass over the distance between the screens, plus the time which the weight of the conjunctor takes to fall from its initial position to

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* Belgian Artillery.

the cup of mercury. Now, to obtain the former, the latter of these times has to be subtracted from the reading of the instrument, and the disjunctor enables us to do this by permitting us to break both currents (those through the first and second screens) simultaneously. The mode of procedure is then as follows:—The instrument being arranged, the two currents are simultaneously broken by means of the disjunctor, and the reading of the needle is recorded. The instrument is again adjusted, the projectile fired the velocity of which it is desired to determine, and the reading of the needle again noted; the former arc is subtracted from the latter, and the corresponding time computed. It will be observed that by the use of the conjunctor any constant source of error (such, for example, as the error due to the time required to clamp the vernier needle) is eliminated, as the same error will occur both in the disjunctor and the projectile reading, and by subtraction will disappear.

The disjunctor also enables us to ascertain the degree of regularity with which the instrument is working, as the accidental variations of the reading corresponding to the time 0, are of course the same as the variations which would occur in the reading corresponding to any other time. Major Navez lays down, as a rule, that observations should not be proceeded with when in a series of ten or twelve disjunctor readings there is between two successive readings a difference greater than $0^\circ \cdot 25$.

6. It is of some importance to be enabled to put an exact estimate on the degree of reliance to be placed on the results of Major Navez's beautiful instrument; and, to do this, let us observe that the arc from which the required time is computed is the difference between two arcs, in our estimation of each of which we are liable to a small error. We have in fact the value of one arc Φ given by the equation

$$\Phi = \varphi - \varphi' \quad \text{.........................} \quad (1)$$

where φ and φ' are each subject to probable errors (let us suppose) r and r'; the probable error of Φ is then $\sqrt{r^2 + r'^2}$. If, after the satisfactory working of the instrument has been ascertained, and the probable error determined, we take a single reading with the disjunctor, and then with the projectile, r and r' are equal, and the probable error of the observation is $r\sqrt{2}$. We have it, however, in our power, if it be thought necessary, to reduce even this error, for if the disjunctor reading be taken, the mean of, say five observations, we have $r' = \frac{r}{\sqrt{5}}$, and the probable error of Φ is $r\sqrt{\frac{6}{5}}$, which differs but slightly from r. An example will show how very trifling this error generally is. With an Armstrong 12-pounder shell, whose velocity is determined to be 1,181 feet per second, the value of r is found to be $0^\circ \cdot 06$, and the disjunctor reading being the mean of five observations, the probable error of Φ is $0^\circ \cdot 07$.

Hence the disjunctor reading being $42^\circ \cdot 85$, and the projectile reading $107^\circ \cdot 40$, it follows that it is probable that in our determination of 1181·2 ft. as the velocity at a point midway between the screens, we do not make an error exceeding 1·4 ft., that is to say, it is an even chance that the true velocity of the single observation lies between 1179·8 ft. and 1182·6 ft. As the round from which the above example is selected is one of a series of 10, the probable error in our determination of the mean velocity between the screens will be less than one-third of that just given, or the mean velocity may be assumed, as far as instrumental errors are concerned, to be practically correct.

7. The experience which I have had with Major Navez's instruments enables me to say, that if ordinary care be taken in their use, and the instructions carefully followed, the instruments are so nearly perfect as to leave little to be desired, while the ease with which they can be manipulated, and the innumerable important problems which can be readily solved by their means render them an invaluable, an almost indispensable adjunct to every school of instruction.

8. Two instruments, Nos. 24 and 32, were used in these experiments. The times of vibrations of the pendulums were carefully determined by means of a stop watch, and the rate of the watch was ascertained by comparison with an astronomical clock. The observations made for this purpose are given in Appendices Nos. I. and II., and from them it appears that the time of a small oscillation in instrument No. 24 is 0·3320 seconds, while in No. 32 it is 0·3337 seconds.

9. In Appendices III. and IV. are given corrected tables showing the relations between the arcs passed through and the corresponding durations for $T = 0{\cdot}3320$ sec. and for $T = 0{\cdot}3337$ sec.

10. The experiments referred to in this report have regard chiefly to initial velocity alone, and for the small distance concerned the law of resistance adopted may be thought of small practical importance, especially as before the experiments now being carried on are concluded, the Committee will doubtless be in a position to say whether this law is better expressed by a function of the form $v^2 + \alpha\, v^3$, as proposed by General Piobert, or by one of the form $v^2 + \beta\, v^4$, as proposed by the Count de St. Robert and Colonel Mayevski. In the present instance, both the law of resistance and the values of the coefficients given by General Didion in his invaluable work have been followed, although it may perhaps be inferred from a passage in the recent edition of the "Traité de Balistique," that late experiments with the electro-ballistic apparatus do not give results in quite so close an accordance with theory as might have been expected.

11. In the first edition of General Didion's work, published in 1848, a term was introduced into the expression of the resistance of the air dependent upon the diameter of the projectile, and this form of the expression has been generally used upon the continent, but a recalculation of the data upon which this result was founded, has led General Didion to conclude that the coefficient is independent of the calibre, and that the resistance is represented with sufficient accuracy by the equation

$$\rho = {\cdot}027\, \pi\, R^2\, v^2 \cdot \frac{\delta}{\delta_1} \left\{ 1 + \frac{v}{435} \right\} \quad \text{.........} \quad (2)$$

where R = radius, v = velocity, δ = density of the air at time of observation, and δ_1 = standard density of air; the metre and the kilogramme are taken as units.

In this formula the density of the air is denoted by referring its weight to a standard of comparison, which is assumed as the weight of a cubic metre of air at a temperature of 15° Centigrade, semi-saturated with vapour, and under a barometric pressure of 750 millimetres.

Now if in equation (2) the English foot and pound be taken as units, the value of the numerical coefficients will be altered, and the equation becomes

$$\rho = {\cdot}0005137\, \pi\, R^2\, v^2 \cdot \frac{\delta}{\delta_1} \left\{ 1 + \frac{v}{1426{\cdot}4} \right\}$$

In the ordinary determinations of initial velocity it is hardly necessary to take the variations of the density of the air into account, and

it only remains so to alter the coefficient ·0005137, that the error arising from neglecting this variation may be as small as possible.

12. According to Regnault, the weight of a cubic foot of dry air at a temperature of 32° Fahrenheit, and under a barometric pressure of 30 inches, is = 566·56 grains; and according to the same author the coefficient of the expansion of the air for an increase in temperature of 1° is = ·002036. Hence if δ be the weight in grains of a cubic foot of dry air at any temperature t, and pressure Π,

$$\delta = \frac{\Pi}{30} \cdot \frac{566{\cdot}56}{1 + {\cdot}002036\,(t^{\circ} - 32^{\circ})}$$

but (see Miller's Hydrostatics, p. 28)—

$$\frac{\text{weight of moist air at any temperature and pressure}}{\text{weight of dry air at same temperature and pressure}} = 1 - 0{\cdot}378\,\frac{T}{\Pi}$$

where T = tension of the aqueous vapour. Hence the density of the air under any circumstances will be found from the following equation:

$$\delta = \frac{\Pi}{30} \cdot \frac{\left(1 - 0{\cdot}378\,\frac{T}{\Pi}\right) 566{\cdot}56}{1 + {\cdot}002036\,(t^{\circ} - 32^{\circ})} \qquad (3)$$

and if we assume as the English standard of comparison the weight of a cubic foot of air at a temperature of 60°, under a barometric pressure of 30 inches, and if we further assume the humidity = 0·5, from (3) we find δ = 534·3 grains, and equation (2) becomes—

$$\rho = {\cdot}0005213\,\pi\,R^2\,v^2 \left(1 + \frac{v}{1426{\cdot}4}\right) \frac{\delta}{534{\cdot}3} \qquad (4)$$

and under ordinary circumstances the fraction $\frac{\delta}{534{\cdot}3}$ may be taken as equal to unity.

13. The above formula (4) applies to spherical projectiles; in the case of the Armstrong projectiles, the resistance of the air is represented by

$$\rho = {\cdot}0003475\,\pi\,R^2\,v^2 \left(1 + \frac{v}{1426{\cdot}4}\right) \frac{\delta}{534{\cdot}3} \qquad (5)$$

The velocity v at a point midway between the screens having been determined by observation, the initial velocity V is deduced from it by the equation—

$$1 + \frac{r}{v} = \left(1 + \frac{r}{V}\right) e^{\frac{x}{2c}} \qquad (6)$$

where r = 1426·4, x = distance, on the axis of the gun produced, of the point corresponding to v, $c = \frac{w}{2\,n\,g}$, w being the weight of the projectile in lbs., g the acceleration of gravity, and n, in the case of spherical projectiles, = ·0005213 π R², in the case of Armstrong projectiles = ·0003475 π R².

14. *Discussion of the Results.* The experiments numbered I. to XXIII. relate solely to the determination of the initial velocity of service projectiles fired from service guns with service charges. The detailed results of the practice furnished *in extenso* give every particular with regard to it, and the following table gives an abstract of the general results.

Table I.

Abstract of the Results of Experiments to ascertain the Initial Velocity of Service Projectiles fired from Service Guns with Service Charges.

Nature of Ordnance.	No. of Rounds.	Charge. Weight.	Charge. Nature of Powder.	Projectile. Nature.	Projectile. Weight.	Projectile. Diam.	Velocity at 30 yds.	Measure of Precision.	Initial Velocity.
10-in. gun, 87 cwt.	10	12 0	L. G. W. A., 26/11/60	Hol. shot	88 5	9·838	1270·4	0·490	1292·3
Do. do.	5	8 0	L. G. Hall and Sons, 22/11/60.	Mar. shell	117 0	9·838	930·1	0·175	940·6
68-pr., 95 cwt. -	12	16 0	L. G. W. A., 26/11/60	Shot -	66 4	7·915	1553·1	0·703	1579·0
Do. do. -	7	16 0	L. G. Hall and Sons, 22/11/60.	Nav. shell	51 8	7·913	1769·4	0·237	1809·9
Do. do. -	9	16 0	Do. do.	Com. shell	49 14	7·857	1750·3	0·348	1790·7
Do. do. -	5	10 0	L. G. Hall and Sons, 22/11/60.	Mar. shell	60 0	7·848	1287·6	0·131	1308·5
8-in gun, 65 cwt.	5	10 0	Do. do.	Hol. shot	46 0	7·84	1455·0	0·504	1487·9
Do. do.	5	10 0	Do. do.	Com. shell	49 14	7·856	1434·6	0·573	1464·4
Do. do.	5	10 0	Do. do.	Nav. shell	51 8	7·92	1475·8	0·306	1506·4
32-pr., 58 cwt. -	10	10 0	L. G. W. A., 26/11/60	Shot -	31 6	6·174	1653·7	0·425	1690·0
Do. do. -	11	8 0	Do. do.	Do. -	31 6	6·176	1584·7	0·640	1618·7
Do. do. -	11	6 0	Do. do.	Do. -	31 6	6·175	1418·8	0·504	1447·5
24-pr., 50 cwt. -	11	8 0	Do. do.	Do. -	23 8	5·602	1679·5	0·323	1720·5
18-pr., 38 cwt. -	12	6 0	Do. do.	Do. -	17 11	5·093	1646·8	0·148	1690·6
12-pr., 18 cwt. -	10	4 0	L. G. - - -	Do. -	12 10½	4·52	1718·6	0·384	1769·8
9-pr., 13 cwt. -	10	2 8	Do. - -	Do. -	9 5¼	4·10	1563·9	0·406	1613·7
6-pr., 6 cwt. -	10	1 8	Do. - -	Do. -	6 3¼	3·58	1435·3	0·418	1484·5
12-pr. howr. 6½ cwt.	10	1 4	Do. - -	Com. shell	8 12	4·454	1124·2	0·270	1163·4
24-pr. do., 12 cwt.	10	2 8	Do. - -	Do. -	16 11½	5·595	1218·0	0·368	1252·7
		drs.							
Wall piece -	8	8	E. R. - - -	Ball -	0 5½	0·935	1134·8	—	1167·6
Enfield rifle -	3	2·5	Do. - - -	M. ball -	530 grs.	0·577	1188·7	—	1272·8
		lbs. oz.							
6-pr. Armstrong -	15	0 12	A. 4, W. A., 5/9/60	Seg. shell	6 0	2·585	937·5	—	946·4
12-pr. do. -	10	1 8	A. 4, W. A. - -	Do. -	11 9	3·084	1180·9	1·000	1190·2

The results with the 6-pounder Armstrong require confirmation.

It will be observed that the values of the "Measure of Precision" for each of the series of which the result is here given is placed in the above table in a separate column. The value of this constant denotes the comparative regularity of the initial velocity.

As might perhaps be expected, from the absence of windage, the 12-pounder Armstrong has shown the greatest regularity, and I have therefore assumed the measure of precision for this gun as unity.

An inspection of the values of the "Measure of Precision" will show how great is the amount of irregularity which exists in the initial velocities of some of the projectiles fired from smooth bored guns.

To illustrate the application of these constants, we may compare their values for the 12-pounder howitzer and the 12-pounder Armstrong, the velocities of the projectiles fired from these guns being nearly the same, but by the table it appears that the measure of precision in the former case is only about one-fourth of that in the latter case, or in other words the mean error in initial velocity alone is nearly four times as great. The great irregularity in the initial velocity of the Martin shells is also very conspicuous.

15. The relation between initial velocity, weight of charge, weight of projectile, and length of bore is given (see Didion, "Traité de Balistique,") by the following equation :—

$$V = \gamma \cdot \sqrt{\frac{\mu}{m + \frac{\mu}{3}} \cdot \log. \frac{M}{\mu} - \frac{C^2 - C'^2}{C^2}} \quad \text{.........} (7)$$

when $V =$ initial velocity, $\mu =$ weight of charge, $m =$ weight of shot, bottom, &c., $M =$ quantity of powder required to fill the bore, $C =$

calibre of gun, $C' =$ diameter of shot. γ and λ are constants whose values have to be determined by experiment. The second term of the night-hand member of equation (7) represents the decrement in initial velocity due to windage, and the value of the coefficient λ should be derived from a series of experiments expressly instituted for the purpose. Strictly speaking this value depends upon a great variety of conditions, but chiefly upon the strength and physical properties of the powder, and upon the length of the bore of the gun. Under normal circumstances, however, a mean value of λ may, with but a very trifling error, be assumed, and General Didion, in his work above referred to, gives $\lambda = 2300$ as the result of the French investigations with the service gunpowder, but an analysis of the above experiments points to a considerably higher value. Indeed, from instances in these experiments, where the variation in windage was sufficiently great, 3158 has been obtained as the mean value of λ, and as this number very nearly agrees with that stated by Colonel Boxer to result from the mean of Major Mordecai's extensive experiments on windage, I have taken as correct the value of λ, viz., 3200, given by that officer.

Assuming λ as above given, γ is easily computed from the data furnished by experiment. γ varies chiefly with the nature and condition of the powder employed, and the annexed table gives the values which have been obtained for the several guns experimented with, and the nature of the powder used in each case.

Table II.

Values of γ for the under-mentioned Smooth bored Guns deduced from the Experiments recorded in Table I.

Nature of Gun.	Nature of Powder.	Value of γ	Nature of Gun.	Nature of Powder.	Value of γ
10-inch gun - -	L. G. W. A.,26/11/60	3284·	24-pr. 50 cwt.	L. G. W. A., 26/11/60 -	3390·
68-pr. 95 cwt. -	L. G. W. A.,26/11/60	3491·	18-pr. 38 cwt.	L. G. W. A., 26/11/60	3454·
Do. do. -	L.G. Hall and Sons, 22/11/60.	3536·	12-pr. 18 cwt.	L. G. - - -	3561·
			9-pr. 13 cwt.	L. G. - - -	3422·
8-inch gun, 65 cwt.	L.G. Hall and Sons, 22/11/60.	3307·	6-pr. 6 cwt. -	L. G. - - -	3321·
			12-pr. Howr.	L. G. - - -	3291·
32-pr. 58 cwt. -	L. G. W.A., 22/11/60	3428·	24-pr. Howr.	L. G. - - -	3275·

The experiments under discussion show that the equation—

$$V = \gamma \cdot \sqrt{\frac{\mu}{m + \frac{\mu}{3}} \cdot \log. \frac{M}{\mu}} - 3200 \frac{C^2 - C'^2}{C^2} \quad \text{.........................} \quad (8)$$

gives the velocity due to a variation in the weight either of the charge or projectile with great exactness, the proper value of γ being used in each series, and this equation has therefore been used to calculate the initial velocities of the various projectiles * thrown from smooth bored guns.

These velocities may be depended upon as correct (supposing the same powder to be used) within very narrow limits, and the computed velocities are in this case perhaps preferable to direct determinations, as, unless the whole series for each gun were carried on at the same time, and with powder of exactly the same nature and date of manufacture, discrepancies from variations in the strength of the powder would be sure to arise.

* The mean weights and windages of the various projectiles have been taken.

Table III.

Table showing the Initial Velocities of the various Service Projectiles fired from the under-mentioned Guns. The velocities printed in italics *are observed. The remainder are calculated from the data furnished by the observed velocities.*

Nature of Ordnance.	Calibre.	Charge.	Projectile. Nature.	Projectile. Weight.	Windage.	Initial Velocity.
	"	lbs.		lbs.	"	Feet per sec.
10-gun, 87 cwt.	10	12	Hol. shot	88·475	·142	*1270·4*
„ „	„	8	Mar. sh.	117·14	·1425	*930·1*
„ „	„	12	Com. sh.	92·625	·15	1257·5
„ „	„	„	Case	77·625	·18	1353·7
„ „	„	„	Grape	83·375	·18	1308·1
68-pr. 95 cwt.	8·12	16	Shot	66·224	·168	*1579·0*
„ „	„	„	Nav. sh.	51·5	·17	*1809·9*
„ „	„	„	Com. sh.	49·875	·226	*1790·7*
„ „	„	10	Mar. sh.	60·0	·235	*1308·5*
„ „	„	16	Diaph. sh.	60·75	·195	1627·9
„ „	„	„	Case	45·687	·265	1818·1
„ „	„	„	Grape	66·5	·3	1475·3
8-gun, 65 cwt.	8·05	10	Hol. shot	46·007	·21	*1487·9*
„ „	„	„	Com. sh.	49·875	·194	*1464·4*
„ „	„	„	Mar. sh.	51·5	·13	*1506·4*
„ „	„	„	Diaph. sh.	60·75	·125	1356·9
„ „	„	„	Case	45·687	·195	1712·7
„ „	„	„	Grape	66·5	·23	1214·4
32-pr. 58 cwt.	6·375	10	Shot	31·375	·196	*1690·0*
„ „	„	8	„	31·389	·194	*1618·7*
„ „	„	6	„	31·349	·195	*1447·5*
„ „	„	10	Com. sh.	24·312	·198	1912·6
„ „	„	„	Diaph. sh.	28·75	·198	1762·4
„ „	„	„	Case	36·094	·228	1543·8
„ „	„	„	Grape	36·25	·228	1540·3
24-pr. 50 cwt.	5·823	8	Shot	23·047	·208	*1720·5*
„ „	„	„	Com. sh.	17·5	·228	1948·2
„ „	„	„	Diaph. sh.	20·875	·228	1786·0
„ „	„	„	Case	25·594	·2435	1594·7
„ „	„	„	Grape	26·0	·253	1571·6
18-pr. 38 cwt.	5·292	6	Shot	17·656	·205	*1690·6*
„ „	„	„	Com. sh.	13·125	·193	1971·6
„ „	„	„	Diaph. sh.	15·875	·193	1797·3
„ „	„	„	Case	19·562	·218	1588·5
„ „	„	„	Grape	19·5	·218	1591·2
12-pr. 18 cwt.	4·623	4	Shot	12·656	·803	*1769·8*
„ „	„	„	Com. sh.	9·0	·169	1987·4
„ „	„	„	Diaph. sh.	10·375	·169	1854·7
„ „	„	„	Case	16·625	·159	1469·8
9-pr. 13 cwt.	4·2	2·5	Shot	9·359	·1	*1613·7*
„ „	„	„	Diaph. sh.	8·062	·12	1707·3
„ „	„	„	Case	13·0	·1315	1318·8
6-pr. 6 cwt.	3·668	1·5	Shot	6·23	·1	*1484·5*
„ „	„	„	Diaph. sh.	5·125	·118	1608·8
„ „	„	„	Case	8·5	·1275	1215·8
12-pr. Howr. 6½ cwt.	4·58	1·25	Com. sh.	9·0	·126	*1144·6*
„ „	„	„	Diaph. sh.	10·465	·126	1058·1
„ „	„	„	Case	8·118	·148	1185·5
24-pr. Howr. 12 cwt.	5·72	2·5	Com. sh.	17·5	·125	*1222·9*
„ „	„	„	Diaph. sh.	20·875	·125	1113·0
„ „	„	„	Case	14·014	·15	1369·9

Variation of the Initial Velocity of the 12-pounder Armstrong in terms of the Weight of the Charge.

16. The decrease in the range of the 12-pounder Armstrong, due to to a slight reduction of the charge, had not, in experimental practice, escaped the notice of the Ordnance Select Committee, and it became a point of interest to determine the dependence of the initial velocity on the charge, and to ascertain if it followed even approximately the same laws as have been laid down for smooth bored guns.

17. The experiments numbered XXXII. to XXXVI. inclusive were undertaken with this view, but in laying down in the form of a diagram the results thus obtained, marked differences were found to exist, which will best be understood by comparing the two curves delineated in fig. 1, in the accompanying diagram. The black line in this diagram shows the relation of the initial velocity to the charge as derived from this series, by actual observation, while the red line denotes the hypothetic relation as determined from the equation—

$$V = 3230 \cdot 8 . \sqrt{\frac{\mu}{m+\frac{\mu}{3}} \log . \frac{18 \cdot 5}{\mu}}$$

where μ and m denote the weight of the charge and shot in lbs., the value of the constant in this equation being determined from the velocity when the service charge of 1 lb. 8 oz. was employed.

It will be observed that while the hypothetic curve is always concave to the line of abscissæ, in the curve derived from actual observation there are two points of inflexion, it being in one portion of its trace convex instead of concave to the axis of x.

18. To check the results obtained in this series, a second series with another gun was subsequently made, the details of which are given in XXXVII. to XLIII. Their graphical representation is delineated in fig. 2., in which as before the black line denotes the observed curve, the red, the computed one, the value of v being given by the equation—

$$V = 3026 \cdot 6 . \sqrt{\frac{\mu}{m+\frac{\mu}{3}} \log . \frac{18 \cdot 5}{\mu}}$$

the coefficient in this case, as in the former, having been determined from the data furnished in the case where the service charge was used.

19. Although in this second case, the initial velocities are, owing to powder of a different strength having been used, very considerably under the velocities in the former case, it will be noticed that the same peculiarities are observable, there being a portion of the curve with its convexity turned towards the axis of abscissæ.

20. The cause of the wide departure from the normal law exhibited in these diagrams is easily explained. It will be remembered that in the Armstrong gun, the shot always occupies a definite position in the bore, the service charge nearly filling the powder chamber. Hence it follows, that if reduced charges be used, additional air space is left in the chamber, so that in addition to the decrement of velocity due to the reduction in the charge, there is to be added the decrement due to the increased air space, and it is easy to see how the combination of these conditions may produce the abnormal results alluded to.

21. The annexed Table gives an abstract of the results of these experiments, and I also attach a table giving for powder of average strength, the initial velocities for various charges.

TABLE IV.

Abstract of the Results of Experiments to ascertain the Initial Velocity of 12-pr. Armstrong Projectiles in Terms of the Weight of the Charge.

Armstrong 12-pr.	No. of Rounds.	Charge.	Projectile. Weight.	Projectile. Diam.	Velocity at 30 yards.	Initial Velocity.	REMARKS.
No. 224	10	1 4	11 9	3·084	1055·3	1063·1	1st series.
	10	1 6	,, ,,	3·085	1092·4	1100·7	
	10	1 8	,, ,,	3·084	1180·9	1190·2	
	10	1 10	,, ,,	3·084	1224·8	1234·6	
	10	1 12	,, ,,	3·084	1262·0	1272·2	
No. 1050	10	0 14	,, ,,	3·084	803·8	809·2	2nd series.
	10	1 0	,, ,,	3·084	863·9	870·0	
	10	1 2	,, ,,	3·084	924·6	931·1	
	10	1 4	,, ,,	3·084	997·8	1005·1	
	10	1 6	,, ,,	3·084	1050·2	1058·0	
	10	1 8	,, ,,	3·084	1106·4	1114·8	
	10	1 10	,, ,,	3·084	1178·0	1187·3	

TABLE V.

Table showing the Velocity of a 12-pr. Armstrong Projectile in relation to the Weight of the Charge.

Weight of Charge.	Initial Velocity.	Weight of Charge.	Initial Velocity.	Weight of Charge.	Initial Velocity.	REMARKS.
lb. oz.	ft.	lb. oz.	ft.	lb. oz.	ft.	
0 14	870	1 3	1,036	1 8	1,190	The weight of the projectile for this table is 11 lb. 9 oz.
0 15	908	1 4	1,063	1 9	1,214	
1 0	943	1 5	1,087	1 10	1,234	
1 1	976	1 6	1,119	1 11	1,254	
1 2	1,007	1 7	1,155	1 12	1,272	

Variation in the Initial Velocity of the Armstrong Projectiles in terms of the Weight of the Shot.

22. From the considerations mentioned in the foregoing paragraph it would naturally be expected, that if the weight of the shot be varied instead of that of the charge, there would be a much smaller discrepancy between the computed and the observed velocities, as in this case the charge remaining the same, there will be no variation in the amount of air space in the powder chamber.

23. The series XXIX. to XXXI. and LIII. to LVII. were undertaken with a view to elucidate this point. A graphical representation of the observed and computed velocities is delineated in fig. 3, the computed velocities being obtained from—

$$V = 3358 \cdot 9 . \sqrt{\frac{\mu}{m + \frac{\mu}{3}} \log . \frac{18 \cdot 5}{\mu}}$$

and a glance will show how closely in this case, the observed velocities accord with the hypothetical ones.

At one point only (where the 9 lbs. projectiles were used), is there any appreciable difference, and this difference is capable of the same explanation as has already been given in par. 20, as, from the construction of this projectile, a greater air space was left in the powder chamber than in the case of the other projectiles, the position of the base of all of which in the bore of the gun was identically the same.

The annexed tables exhibit an analysis of the results obtained from these experiments.

TABLE VI.

Abstract of the Results of the Experiments made to determine the Initial Velocity of Projectiles fired from the 12-pr. Armstrong Gun, the Weight of the Shot being varied.

Armstrong 12-pounder.	No. of Rounds.	Charge.	Projectile.		Velocity at 30 Yards.	Initial Velocity.	
			Weight.	Diameter.		Observed.	Computed.
No. 224	11	1 8	11 13	3·084	1164·5	1173·4	—
	11	„ „	11 5	3·084	1192·9	1202·5	—
	10	„ „	10 13	3·084	1209·8	1220·1	—
No. 1,050	5	„ „	9 0	3·074	1322·3	1336·3	1384·0
	6	„ „	11 9	3·084	1227·4	1237·2	1237·0
	6	„ „	24 6	3·084	853·9	856·7	860·3
	6	„ „	35 14	3·084	720·0	721·5	710·1
	5	„ „	47 13	3·084	613·9	614·8	618·1

TABLE VII.

Table showing the Velocity of Projectiles of various Weights fired from a 12-pr. Armstrong Gun.

Charge.	Weight of Shot.	Initial Velocity.	Charge.	Weight of Shot.	Initial Velocity.	Charge.	Weight of Shot.	Initial Velocity.
1 8	9 0	1380	1 8	22 0	900	1 8	35 0	730
„ „	10 0	1321	„ „	23 0	881	„ „	36 0	720
„ „	11 0	1266	„ „	24 0	864	„ „	37 0	710
„ „	12 0	1213	„ „	25 0	850	„ „	38 0	700
„ „	13 0	1174	„ „	26 0	835	„ „	39 0	691
„ „	14 0	1134	„ „	27 0	827	„ „	40 0	682
„ „	15 0	1095	„ „	28 0	810	„ „	41 0	673
„ „	16 0	1060	„ „	29 0	797	„ „	42 0	664
„ „	17 0	1027	„ „	30 0	785	„ „	43 0	655
„ „	18 0	997	„ „	31 0	773	„ „	44 0	646
„ „	19 0	970	„ „	32 0	762	„ „	45 0	638
„ „	20 0	945	„ „	33 0	751	„ „	46 0	630
„ „	21 0	923	„ „	34 0	740	„ „	47 0	622

Variation in Initial Velocity between high and low Gauge Projectiles (Armstrong).

24. The experiments numbered XLIV. to XLVII. were made with a view to ascertain whether there is any difference in velocity between projectiles of the highest and lowest gauges admitted into the service.

The results of these experiments are here given, and it will be seen that there exists between the velocities no appreciable difference.

Table VIII.

Abstract of the Results of the Experiments made to ascertain the Difference in Initial Velocity between High and Low Gauge Projectiles.

Armstrong 12-pounder.	No. of Rounds.	Charge.	Projectile.		Velocity at 30 Yards.	Initial Velocity.	Remarks.
			Weight.	Diameter.			
		lbs. oz.	lbs. oz.				
No. 224.	5	1 8	11 9	3·080	1184·1	1193·4	Bore washed.
	6	,, ,,	,, ,,	3·085	1177·2	1186·5	
	11	,, ,,	,, ,,	3·080	1184·1	1193·4	Lubricating wads used.
	8	,, ,,	,, ,,	3·085	1187·8	1197·1	

25. In the series numbered XLVIII. to LI. are given the comparative initial velocities of the old (A) and new (Q) pattern 12-pr. shells, both with and without lubricating wads.

It will be seen that while the old pattern shell has, although scarcely appreciable, a slightly higher initial velocity, due to the greater diameter at the back end, the introduction of the lubricating wads adds to the velocity about 15 feet.

The effect of the greater diameter at the back end will be again referred to; but it is interesting to observe that while the initial velocity is increased by offering, in the first instance, increased resistance to the motion of the projectile, it is also increased by diminishing as much as possible the resistance of the friction in its passage through the bore. The explanation of these results is too obvious to require remark.

Table IX.

Abstract of Experiments made to ascertain the Difference in Initial Velocity of old and new Pattern 12-pr. Shells, with and without Lubricating Wads.

Armstrong 12-pounder.	No. of Rounds.	Charge.	Projectile.		Velocity at 30 Yards.	Initial Velocity.	Remarks.
			Weight.	Diameter.			
		lbs. oz.	lbs. oz.				
No. 224.	15	1 8	11 9	3·072	1154·2	1163·2	Q pattern shell, lubricating wad.
	14	,, ,,	,, ,,	3·085	1157·1	1166·1	A ,, ,, ,, ,,
	13	,, ,,	,, ,,	3·072	1142·0	1150·8	Q ,, ,, bore washed.
	10	,, ,,	,, ,,	3·085	1140·6	1149·4	A ,, ,, ,, ,,

26. The annexed table gives an abstract of the experiments made to compare the initial velocities of shell of the same form and weight, fired from rifled and smooth bored 32-prs. of 58 cwt. The ribbed shell was, in the first case, fired from the rifled gun. Shells of the same form, diameter, and weight, but with the ribs removed, were then fired from the rifled gun, and finally similar shells were fired from a smooth bored 32-pr.

The velocities in these three cases were respectively 1224·5, 1135·3, and 1201·7 ft. per second. The great difference in velocity in the

second case is due to the escape of gas by the grooves in the rifled gun.

Table X.

Abstract of Experiments to ascertain the comparative Velocities of the same Shell fired from rifled and smooth bored 32-prs. of 58 cwt.

Nature of Gun.	Charge.	Projectile. Nature.	Projectile. Weight.	Projectile. Diameter.	Velocity at 30 Yards.	Initial Velocity.	Remarks.
	lbs. oz.		lbs. oz.				
32-pr. rifled	5 8	Pl. shell	54 0	6·350	1215·7	1224·5	—
" "	" "	" "	54 0	6·350	1122·1	1135·3	Nibs of shell removed.
32-pr. 58 cwt.	" "	" "	54 0	6·350	1187·4	1201·7	Do. do.

27. With the same rifled 32-pr. gun experiments were also made to ascertain the reduction in the initial velocity due to an elongation in the cartridge, and the results of these experiments are here tabulated.

Table XI.

Abstract of Experiments made to ascertain the Initial Velocities of Projectiles fired from a 32-pr. rifled Shunt Gun, with Charges made up in Cartridges of various Lengths.

Nature of Gun.	No. of Rounds.	Cartridge. Charge.	Cartridge. Length.	Projectile. Nature.	Projectile. Weight.	Projectile. Diameter.	Velocity at 30 Yards.	Initial Velocity.	Remarks.
		lbs. oz.			lbs. oz.				
Rifled 32-pr.	4	5 8	12 ins.	Plugged shell.	54 0	6·350	1054·6	1061·7	—
	3	" "	9 "		" "	6·350	1076·8	1084·2	
	1	" "	8 "		" "	6·350	1102·2	1109·8	
	1	" "	7½ "		" "	6·350	1114·5	1122·3	
	2	" "	6 "		" "	6·350	1187·9	1196·4	

From the rapid decrease in the initial velocity shown in this table, the effect of the variation in air space in the 12-pr. Armstrong, to which I have already alluded, will be easily understood.

28. The experience of the preceding practice, together with theoretical considerations, having pointed to a probable decrease in velocity should the diameter of the projectiles be diminished or reduced to that of the bore, the experiments numbered LXIX. to LXXII. were undertaken with the object of corroborating or disproving this view.

From the abstract of this interesting series it will be seen that while the velocity of the projectiles under normal circumstances was 1248·2 ft. per second, when their diameter was reduced to that of the bore, with the exception of a narrow band at the back end, it became only 1209·7 ft. per second; and when the diameter was finally reduced throughout to that of the bore, it was reduced to 1172·8 feet. In the rounds fired with the reduced diameters, the projectiles in all cases appeared to be perfectly steady in flight.

TABLE XII.

Abstracts of Experiments made to determine the Effect on the Initial Velocity of diminishing the Lead on the 12-pounder Armstrong Projectiles.

Armstrong 12-pounder.	No. of Rounds.	Charge.	Projectile.		Velocity at 30 Yards.	Initial Velocity.	REMARKS.
			Weight.	Diameter.			
		lbs. oz.	lbs. oz.				
No. 1050.	4	1 8	11 9	3·074	1238·3	1248·2	Shell fired under normal circumstances.
	2	„ „	„ „	3·010	1200·2	1209·7	Same shell reduced to the diameter of 3·01, with the exception of a ring at the base ·25 inches broad.
	2	„ „	„ „	3·010	1163·7	1172·8	Same shell reduced throughout.

29. The experiments with the Armstrong 12-pr. having been chiefly carried on with the same gun, the initial velocities obtained under similar circumstances become a measure of the variability, in strength, of the service gunpowder, and it is somewhat surprising to find so great a variation in powder recently made and professedly of the same make. For illustration of this remark, I may point to the differences in initial velocity exhibited in figs. 1 and 2. In this case, it is true, the results were obtained from different guns; but under similar circumstances, these guns were found to give nearly identical velocities. Another even stronger case, however, may be taken from the velocities given on different occasions by the gun numbered 1050. Thus, on the 12th March 1861, with a service charge of powder marked (A. 4, W. A., 5/9/60, lot 288), the initial velocity was found to be 1114·8 feet, while under precisely the same circumstances, on the 15th March 1861, with powder marked (A. 4, Hall and Sons, 11/7/60, lot 2), the initial velocity was 1248·2 feet per second. I may observe that with the Armstrong 12-pr., when the same powder is used, the variation in initial velocity is very slight, the extreme difference in 10 rounds rarely exceeding 20 feet.

30. On actual service it is obvious that the strength of the powder may be expected to vary considerably more than is here indicated; and I venture to draw the attention of the Select Committee to this point, as one seriously affecting the precision of rifled, or indeed of any guns, and as a case in which the electro-ballistic apparatus might be most advantageously employed.

31. My attention during these experiments was early drawn to the ranges obtained at P. B., and at small angles of elevation, with the 12-pr. Armstrong. These ranges considerably exceeded those of the smooth bored field service guns, although, of course, the initial velocity in these latter is very much higher. I therefore took the usual steps for ascertaining the "angle of departure," and, as much additional trouble was not entailed, I also made arrangements for ascertaining the ordinates at various points of the trajectory. It will be seen by these observations that the angle of projection of a projectile fired from a 12-pr. gun, accurately laid with its bore horizontal, varied from 0° 23′ 30″ to 0° 28′ 28″, the mean angle of projection being 25′ 33″, while in the same gun fired with an elevation of 30′, the angle of projection varied from 47′ 0″ to 49′ 6″, the mean angle being 48′ 18″.

In figs. 4, 5, and 6, I have laid down, for the information of the Committee, the mean results of this practice, the observed trajectories being denoted by black, the computed by red, and for the sake of comparison I have also shown, in blue lines, the departure of both curves from the parabolic.

The annexed abstract will show how close is the agreement between the computed and observed ordinates in the curves delineated; while a similar comparison for the majority of the curves observed, is made in the detailed report of of the practice furnished herewith.

TABLE XIII.

Abstract of the Results of the Experiments made to ascertain the Angle of Projection and the Trajectories of the 12-pr. Armstrong Projectiles when fired P. B., and at an apparent Elevation of 30′.

Elevation given.	Angle of Departure.	Velocity at 30 Yards.	Initial Velocity.	Ordinates at 90 feet.		Ordinates at 150 feet.		Ordinates at 300 feet.	
				Obs.	Com.	Obs.	Com.	Obs.	Com.
° ′	° ′ ″	ft. per sec.	ft. per sec.						
0 0	0 25 44	1188·1	1197·5	4·832	4·832	5·083	5·097	5·444	5·459
0 0	0 25 55	1170·7	1179·8	4·834	4·832	5·085	5·118	5·472	5·443
0 30	0 48 35	1179·6	1188·9	5·431	5·441	—	—	7·421	7·44

(*continued*)

450 feet.		600 feet.		750 feet.		900 feet.		1,050 feet.		1,200 feet.		1,355 feet.	
Obs.	Com.	Obs.	Com.	Obs.	Com.	Obs.	Com.	Obs.	Com.	Obs.	Com.	Obs.	Com.
5·2	5·255	4·527	4·483	3·417	3·133	·869	1·003	—	—	—	—	—	—
5·202	5·207	4·425	4·359	2·75	2·97	—	—	—	—	—	—	—	—
8·359	8·329	8·465	8·414	8·133	8·025	7·089	7·056	—	5·428	—	3·033	0·45	0·01

32. I may observe that the ordinates were first calculated upon the hypothesis that the resistance of the air was given by the equation

$$\rho = \cdot 0003475\,\pi\,R^2\,v^2\,\frac{\delta}{534\cdot 3}\left\{1 + \frac{v}{1+1426\cdot 4}\right\}$$

but it was found that the actual ordinates were more nearly represented by using the same constant (·0005213) as is used for smooth bored projectiles.

The accordance of the ordinates calculated on this hypothesis are, on the whole, exceedingly close; but it would be unwise to place too great dependence upon the results of experiments so partial, and carried on at such low angles.

33. The following table gives an abstract of the results of several miscellaneous experiments :—

TABLE XII.

Nature of Gun.	Charge.	Projectile. Nature.	Projectile. Charge.	Projectile. Diameter.	Velocity at 30 Yards.	Initial Velocity.	REMARKS.
	lbs. oz.		lbs. oz.				
9-pr. brass, 13½ cwt.	0 14	Shot	9 5	4·080	1011·2	—	At 25 yards.
	1 8	do.	9 5	4·080	1310·9	—	
12-pr., 8½ cwt., Armstrong.	1 2	S. shell	9 0	3·074	1130·0	1141·2	Experiments to ascertain the initial velocity of a 9-pr. shell with a charge of 1 lb. 2 oz.
12-pr., 6 cwt., Armstrong.	1 6	do.	11 9	3·074	1103·4	1111·8	Experiments to ascertain the initial velocities of 12-pr. shells, fired from a 12-pr. gun of 6 cwt.
12-pr., 8½ cwt., Arm. No. 8.	1 8	do.	11 9	3·084	1127·6	1136·3	Experiments to ascertain the difference in initial velocity and regularity of two 12-prs., the first of which had been exposed to the weather for several weeks.
12-pr., 8½ cwt., Arm. No. 224.	1 8	do.	11 9	3·084	1141·8	1150·6	

Experiments to ascertain the initial velocity of the old pattern (25 lbs.) projectiles fired from 20-pr. guns.

Nature of Gun.	Charge.	Projectile. Nature.	Projectile. Charge.	Projectile. Diameter.	Velocity at 30 Yards.	Initial Velocity.	REMARKS.
	lbs. oz.		lbs. oz.				
Long 25-pr. Armstrong, R.G.H. No. 384.	2 8	S. shell	25 0	3·830	963·8	968·8	Without lubricating wads.
	" "	do.	" "	"	1014·4	1019·8	Lubricating wads used.
	2 13	do.	" "	"	1083·3	1089·3	
	3 2	do.	" "	"	1136·1	1142·5	
Short 25-pr. Armstrong, No. 403.	2 6	do.	" "	"	874·5	878·9	

March 7, 1861.—Barometer (32°), 30·050. Therm. (dry), 51°·0. Therm., wet, 49°·0. Elastic force of vapour, ·321. Humidity, ·86. Weight of cubic foot of air, 544·2 grs. To ascertain the initial velocities of the 10-in. hollow shot and Martin's shells, fired with service charges.

	No. of Rounds.	Nature of Ordnance.	Charge.	Projectile. Nature.	Projectile. Diameter.	Projectile. Weight.	Recoil.	Reading of Needle. Disjunctor.	Reading of Needle. Projectile.	Velocity. At 30 yds.	Velocity. Initial.	Range.	Remarks.
			lbs. oz.			lbs. oz.	′ ″	°	°	ft.	ft.	yds.	
I.	1	10-in. gun, No. 6,631. Weight, 87 cwt. 1 qr. Calibre, 9·980 ins.	12 8	10-in. plugged shell as hollow shot.	9·83	88 12	—	43·65	103·80	1270·1	1292·3 Mean 1270·4	337·8	Gun laid p. b. every round with spirit level. Mounted on a rear chock carriage weight. Slope of platform, 5°. * Observation destroyed by proof. † Not observed. ‡ Signal mistaken. Weight of carriage, 20 cwt. 1 qr. Powder, L. G., W. A., 26/11/60. Lot 260 for hollow shot. L. G., Hall and Sons, 22/11/60. Lot 814.
	2		„ „		9·84	87 12	—	43·80	*	—		324·	
	3		„ „		9·84	88 4	—	43·70	102·65	1296·3		373·5	
	4		„ „		9·84	87 8	—	43·85	103·75	1271·2		385·5	
	5		„ „		9·84	89 0	6 6	43·85	103·55	1275·7		382·5	
	6		„ „		9·83	87 8	6 6½	43·85	103·65	1273·5		—	
	7		„ „		9·84	88 8	6 8½	43·60	104·35	1257·8		358·7	
	8		„ „		9·85	89 12	6 5	43·85	105·60	1230·7		360·	
	9		„ „		9·84	89 8	6 9	43·85	104·05	1264·5		382·	
	10		„ „		9·83	89 0	6 5	43·60	104·05	1264·5		496·3	
	11		„ „		9·83	88 4	6 11	44·00	†	—		254·3	
	12		„ „		9·84	87 0	6 11	43·90	102·70	1299·3		264·	
II.	13		8 0	10-in Martin's shells rivetted.	9·84	117 4	5 8½	43·90	121·45	951·7	940·6 Mean 930·1	383·	
	14		„ „		9·84	117 0	5 9	37·10	118·75	904·3		391·5	
	15		„ „		9·84	117 1	5 9	37·25	119·45	895·2		389·7	
	16		„ „		9·83	117 4	5 10	37·10	114·00	969·2		335·	
	17		„ „		9·84	116 13	5 9	37·00	‡	—		357·0	

March 8, 1861.—Bar. (32°), 30·170. Therm. (dry), 54°·3. Therm., wet, 51°·8. Elastic force of vapour, ·352. Humidity, ·833. Weight of cubic foot of air, 542·6 grs. To ascertain the initial velocities of the 68-pr. shot, naval, common, and Martin's shells, fired with service charges.

	No. of Rounds.	Nature of Ordnance.	Charge.	Projectile. Nature.	Projectile. Diameter.	Projectile. Weight.	Recoil.	Reading of Needle. Disjunctor.	Reading of Needle. Projectile.	Velocity. At 30 yds.	Velocity. Initial.	Range.	Remarks.
			lbs. oz.			lbs. oz.	′ ″	°	°	ft.	ft.	yds.	
III.	1	68-pr. gun, No. 7,965. Weight, 95 cwt. 2 qrs. Calibre, 8·083 in.	16 0	68-pr. solid shot.	7·92	66 4	*4 2*	39·75	88·25	1568·4	1579·0 Mean 1553·3	337·7	Gun laid horizontal by spirit level every round. Height of axis of gun above plane, 4 ft. 3 in. Carriage rear chock. Slope of platform, 5°. Recoil printed in *italics* denotes that the break was employed. In other cases the break was not used. * Not observed. Weight of carriage, 17 cwt. 12 lbs. Powder, L. G., W. A., 26/11/60. Lot 260 for 68-pr., solid shot. L. G., Hall and Sons 22/11/60. Lot 814 for rest of 68-pr. experiments.
	2		„ „		7·92	66 3	5 7	49·10	99·25	1544·0		324·0	
	3		„ „		7·91	66 3	5 10½	49·35	99·10	1548·9		373·5	
	4		„ „		7·92	66 4	5 10½	49·55	99·90	1523·3		385·5	
	5		„ „		7·91	66 4	6 0	47·75	97·35	1555·3		382·5	
	6		„ „		7·91	66 3	6 0	47·80	97·45	1552·1		434·0	
	7		„ „		7·92	66 3	*4 5½*	47·75	97·55	1548·8		358·7	
	8		„ „		7·91	66 3	*4 11½*	47·85	96·65	1578·3		360·0	
	9		„ „		7·92	66 3	*4 7*	47·90	97·05	1565·1		382·0	
	10		„ „		7·91	66 4	*4 9½*	47·40	96·95	1555·1		496·3	
	11		„ „		7·91	66 5	*5 0½*	47·50	97·00	1553·5		254·4	
	12		„ „		7·92	66 4	*5 1*	47·45	97·20	1547·1		264·0	
IV.	13		„ „	8-in. naval shell.	7·91	51 8	*4 2½*	47·50	91·05	1769·2	1809·9 Mean 1769·4	383·0	
	14		„ „		7·91	51 8	*4 4*	47·55	90·30	1800·3		391·5	
	15		„ „		7·92	51 8	*3 10*	47·35	90·50	1791·9		389·7	
	16		„ „		7·91	51 8	*4 5*	47·55	*	—		335·0	
	17		„ „		7·91	51 8	*3 9*	47·20	90·60	1787·7		356·9	
	18		„ „		7·91	51 8	*3 11*	47·35	90·70	1783·6		312·1	
	19		„ „		7·91	51 8	*3 10*	47·45	93·35	1679·7		323·8	
	20		„ „		7·92	51 8	*4 1*	47·30	90·95	1773·3		568·3	
	21		„ „		7·92	51 8	5 9	47·40	*	—		358·0	
V.	22		„ „		7·91	51 8	5 6	—	*	—		357·9	
	23		„ „	8-in. com. shell.	7·87	49 14	5 3	—	*	—	1790·7 Mean 1750·3	323·1	
	24		„ „		7·85	49 14	5 6	47·95	93·10	1707·8		359·0	
	25		„ „		7·86	49 14	*3 8*	47·85	91·30	1779·4		360·0	
	26		„ „		7·84	49 14	*3 9*	47·45	*	—		356·0	
	27		„ „		7·84	49 14	*4 0*	47·75	92·10	1738·8		383·3	
	28		„ „		7·85	49 14	*3 7*	47·85	92·25	1732·8		286·0	
	29		„ „		7·87	49 14	*4 0*	47·80	91·75	1753·4		382·0	
	30		„ „		7·85	49 14	*4 2*	48·15	91·95	1765·4		—	
	31		„ „		7·87	49 14	*4 0*	48·15	91·85	1769·4		—	
	32		„ „		7·87	49 14	5 4	48·25	92·20	1755·2		385·8	
VI.	33		10 0	8-in. Martin's rivetted.	7·85	60 0	3 5	48·20	105·30	1339·2	1308·5 Mean 1287·6	394·2	
	34		„ „		7·83	60 0	3 6	39·45	98·75	1283·0		310·9	
	35		„ „		7·87	60 2	3 7	39·50	100·65	1242·0		277·4	
	36		„ „		7·84	60 0	3 7	39·45	96·10	1344·2		358·1	
	37		„ „		7·85	60 0	3 7	39·65	101·25	1229·4		326·4	

March 15, 1861.—Barometer (32°), 30°·245. Therm. (dry), 53°·3. Therm., wet, 48°·1. Elastic force of vapour, ·268. Humidity, ·67. Weight of cubic foot of air, 535·2 grs. To ascertain the initial velocity of the 8-in. hollow shot, common shell, and naval shell fired with service charges.

No. of Rounds.		Nature of Ordnance.	Charge.	Projectile. Nature.	Projectile. Diameter.	Projectile. Weight.	Recoil.	Reading of Needle. Disjunctor.	Reading of Needle. Projectile.	Velocity. At 30 yds.	Velocity. Initial.	Range.	Remarks.
			lbs. oz.			lbs. oz.	′ ″	°	°	ft.	ft.	yds.	
VII.	1	8-pr. gun, No. 5,973. Weight, 65 cwt. 3 qrs. 14 lbs. Calibre.	10 0	8-in. com. shell as hollow shot.	7·88	46 0	9 0	32·20	82·75	1466·9		263·6	Gun laid horizontal by spirit level every round. Gun mounted on a rear chock carriage. Weight of carriage 13 cwt. Slope of platform, 5°. Powder, Hall and Sons, 22/11/60. Lot 814.
	2		,, ,,		7·83	46 0	8 4	40·40	92·60	1463·9		263·6	
	3		,, ,,		7·84	46 0	8 4	40·55	92·65	1462·5	1487·9	199·6	
	4		,, ,,		7·85	46 4	8 9	40·25	93·35	1443·0	Mean	—	
	5		,, ,,		7·83	46 2	8 5	40·65	93·50	1438·9	1455·0	276·3	
VIII.	6		,, ,,	8-in. com. shell, loose.	7·86	49 14	8 7	40·70	94·20	1420·1		333·6	
	7		,, ,,		7·84	49 14	8 6	41·05	93·90	1438·6		253·0	
	8		,, ,,		7·84	49 14	8 9	40·85	94·00	1435·9	1464·4	253·3	
	9		,, ,,		7·87	49 14	9 1	40·85	93·70	1444·0	Mean	254·3	
	10		,, ,,		7·87	49 14	9 0	40·75	94·05	1434·5	1434·6	248·0	
IX.	11		,, ,,	8-in. naval shell.	7·91	51 8	9 10	40·80	91·70	1500·9		276·6	
	12		,, ,,		7·93	51 8	9 11	40·55	92·85	1462·8		297·3	
	13		,, ,,		7·92	51 8	*	40·70	92·80	1462·4	1506·4	281·0	
	14		,, ,,		7·92	51 8	*	40·75	91·65	1497·2	Mean	246·0	
	15		,, ,,		7·92	51 8	*	40·80	93·10	1455·8	1475·8	244·6	

March 9, 1861.—Barometer (32°), 30°·530. Therm. (dry), 50°·3; wet, 43°·8. Elasticity, ·201. Humidity, ·54. Weight of cubic foot of air, 554·5 grs. Experiments to ascertain the initial velocity of 32-pr. solid shot with 10, 8, and 6 lbs. charges, and of 24-pr. solid shot with 8 lbs. charges.

No. of Rounds.		Nature of Ordnance.	Charge.	Projectile. Nature.	Projectile. Diameter.	Projectile. Weight.	Recoil.	Reading of Needle. Disjunctor.	Reading of Needle. Projectile.	Velocity. At 30 yds.	Velocity. Initial.	Range.	Remarks.
			lbs. oz.			lbs. oz.	′ ″	°	°	ft.	ft.	yds.	
X.	1	32-pr., 58 cwt., gun, No. 6,966. Weight, 58 cwt. 3 qrs. Calibre, 6·370.	10 0	32-pr. solid shot.	6·17	31 6	3 6	39·30	85·95	1627·2		310·6	9/3/61. Gun laid horizontal by spirit level every round. Height of axis of gun above plane 4′ 3½″. Gun mounted on a rear chock carriage. Slope of platform 5°. Weight of carriage, 16 cwt. 2 qrs. Powder, L.G., W. A., 26/11/60. Lot 260. Recoil printed in *italics* denotes that the break was used. In other cases the break was not used. * Not observed.
	2		,, ,,		6·17	31 5	4 3	48·55	95·10	1661·5		310·7	
	3		,, ,,		6·18	31 5	4 0	48·70	95·60	1643·4		327·0	
	4		,, ,,		6·16	31 5½	4 3½	—	—	—		320·6	
	5		,, ,,		6·16	31 7	4 5	48·30	*	—		292·0	
	6		,, ,,		6·17	31 5½	4 6	48·20	94·30	1678·3	1690·0	328·3	
	7		,, ,,		6·17	31 6	*2 11*	48·35	96·00	1617·2		325·0	
	8		,, ,,		6·17	31 6	*3 1*	48·20	94·85	1658·1		299·9	
	9		,, ,,		6·18	31 7	*3 1*	48·40	95·05	1650·9		318·3	
	10		,, ,,		6·17	31 7	*3 3*	48·30	94·85	1658·1	Mean	—	
	11		,, ,,		6·18	31 6	*3 3*	48·60	94·25	1693·1	1653·7	371·6	
	12		,, ,,		6·18	31 6½	*3 3*	48·65	95·40	1650·5		330·6	
XI.	13		8 0		6·18	31 6½	3 9	41·20	88·70	1606·8		290·0	
	14		,, ,,		6·18	31 6½	3 8	46·85	95·80	1575·2		—	
	15		,, ,,		6·18	31 7	3 9	46·95	96·00	1568·4		325·3	
	16		,, ,,		6·17	31 6	3 8	47·05	95·75	1585·5		299·1	
	17		,, ,,		6·18	31 7	3 7	47·20	95·30	1600·7		310·8	
	18		,, ,,		6·18	31 7	3 9	47·20	95·80	1583·8	1618·7	325·4	
	19		,, ,,		6·17	31 6	*2 7*	46·90	96·15	1563·1		—	
	20		,, ,,		6·17	31 5	3 9	46·80	95·55	1582·8		380·0	
	21		,, ,,		6·18	31 6	3 4½	46·85	95·55	1582·8	Mean	369·8	
	22		,, ,,		6·17	31 5½	3 5	46·90	95·00	1601·3	1584·7	326·7	
	23		,, ,,		6·18	31 6	3 10	46·95	95·60	1581·1		330·3	
XII.	24		6 0		6·16	31 5	2 6	46·95	102·25	1384·6		—	
	25		,, ,,		6·19	31 6½	2 5	46·95	100·50	1432·0		—	
	26		,, ,,		6·18	31 5	2 4	46·85	101·20	1412·7		329·0	
	27		,, ,,		6·17	31 7	2 6	46·95	100·75	1425·1		244·6	
	28		,, ,,		6·18	31 5	2 5	46·90	101·10	1415·5		257·6	
	29		,, ,,		6·17	31 6	2 4	46·90	100·70	1426·5		248·6	
	30		,, ,,		6·18	31 5½	2 5	46·95	100·45	1433·4	1447·5	322·8	
	31		,, ,,		6·18	31 6	2 6	46·95	101·30	1410·0		299·4	
	32		,, ,,		6·17	31 5	2 9	46·80	101·20	1412·7	Mean	301·3	
	33		,, ,,		6·18	31 5	2 6	46·85	99·95	1447·6	1418·8	243·1	
	34		,, ,,		6·17	31 5½	2 6	46·85	*	—		291·5	
	35		,, ,,		6·16	31 5½	2 5	46·85	101·40	1407·3		238·5	
XIII.	1	24-pr., 50 cwt. No. right trunnion 9; left trunnion, 2. Weight, 49 cwt. 2 qrs. 14 lbs. Calibre, 5·810.	8 0	24-pr. solid shot.	5·61	23 7	4 11	46·95	94·45	1626·0		301·0	Gun laid horizontal. Height of axis of gun, 5 ft. Travelling carriage. Slope of platform, 3°. Powder, L. G., W. A., 26/11/60. Lot 260.
	2		,, ,,		5·59	23 8	5 0	47·00	93·40	1663·4		—	
	3		,, ,,		5·60	23 8	5 4	47·00	93·05	1676·2		253·0	
	4		,, ,,		5·60	23 8	6 0	47·05	92·40	1700·5		302·0	
	5		,, ,,		5·59	23 7	6 3	47·00	92·50	1696·8		324·0	
	6		,, ,,		5·60	23 8	6 0	46·95	—	—		351·0	
	7		,, ,,		5·60	23 8	—	47·00	93·45	1661·6	1720·5	266·0	
	8		,, ,,		5·60	23 7	—	47·10	93·00	1678·1		327·0	
	9		,, ,,		5·61	23 8	5 0	47·10	92·75	1687·4		355·0	
	10		,, ,,		5·60	23 7	5 0	47·15	91·60	1731·4	Mean	362·0	
	11		,, ,,		5·61	23 7	5 8	47·10	93·45	1661·6	1679·5	359·0	
	12		,, ,,		5·61	23 7	—	47·10	92·65	1691·1		379·0	

March 10, 1861. Barometer (32°), 30·450. Thermometer, dry, 48°·2. Thermometer, wet, 46°·0. Elastic force of vapour, ·210. Humidity, ·52. Weight of cubic foot of air, 554·0 grs. To ascertain the initial velocity of the 18-pr. solid shot.

No. of Rounds.	Nature of Ordnance.	Charge.	Projectile. Nature.	Projectile. Diameter.	Projectile. Weight.	Recoil.	Reading of Needle. Disjunctor.	Reading of Needle. Projectile.	Velocity. At 30 yds.	Velocity. Initial.	Range.	Remarks.
		lbs. oz.			lbs. oz.		°	°	ft.	ft.	yds.	
XIV. 1	18-pr. gun, No. 76,682. Weight, 57 cwt. 3 qrs. 21 lbs. Calibre, 5″·798.	6 0	18-pr. solid shot.	5·10	17 11	3 7	46·95	93·85	1646·9		—	Gun laid horizontal every round, mounted on a travelling carriage. Slope of platform, 3°. Height of axis above plane, 4′ 9″. Powder, L. G., W. A., 26/11/60. Lot 260.
2		,, ,,		5·10	17 10	4 1	47·05	92·30	1703·9		—	
3		,, ,,		5·08	17 11	4 3	46·95	94·20	1634·4		—	
4		,, ,,		5·09	17 10	4 0	47·10	94·05	1639·7		—	
5		,, ,,		5·09	17 10	3 10	47·10	96·35	1561·6		521·8	
6		,, ,,		5·09	17 10	4 $4\frac{1}{2}$	47·05	93·05	1675·8	1690·6 Mean 1646·8	376·5	
7		,, ,,		5·09	17 10	3 9	47·30	96·00	1586·8		371·3	
8		,, ,,		5·09	17 10	4 2	47·40	96·30	1576·8		370·0	
9		,, ,,		5·10	17 11	4 0	47·40	91·00	1771·8		350·0	
10		,, ,,		5·10	17 11	—	47·45	94·15	1651·0		450·0	
11		,, ,,		5·09	17 11	4 2	47·50	95·10	1617·5		382·1	
12		,, ,,		5·09	17 11	3 9	47·55	92·95	1695·2		352·1	

October 18, 1860. Barometer (32°), 30·050. Thermometer, dry, 56°·2; wet, 52°·0. Wind, calm. Elastic force of vapour, ·338. Humidity, ·75. Weight of cubic foot of air, 537 grs. To ascertain the initial velocity of 12-pr. solid shot.

		lbs. oz.			lbs. oz.		°	°	ft.	ft.	yds.	
XV. 1	12-pr. brass gun, No. 772. Weight, 18 cwt. 0 qrs. 2 lbs. Calibre, .	4 0	12-pr. solid shot.	4·52	12 $10\frac{1}{2}$	Not observed.	41·75	86·40	1718·9		384·0	* Shot with wooden bottoms. Gun laid horizontal every round. Height of axis of gun . Gun was mounted on a travelling carriage. Powder, service, all out of same barrel.
2		,, ,,		,,	,, ,,		50·00	95·30	1724·8		366	
3		,, ,,		,,	,, ,,		50·25	95·25	1726·8		322	
4		,, ,,		,,	,, ,,		50·45	95·20	1728·8		394	
5		,, ,,		,,	,, ,,		50·40	95·75	1707·3	1769·8 Mean 1718·6	280	
6		,, ,,		,,	,, ,,		50·50	95·30	1724·8		320	
7		,, ,,		,,	,, ,,		50·00	96·35	1684·5		396	
8		,, ,,		,,	,, ,,		50·20	96·20	1690·2		345	
9		,, ,,		,,	,, ,,		50·05	94·15	1771·1		328	
10		,, ,,		,,	,, ,,		50·20	95·70	1709·3		370	

September 17, 1860. Barometer (32°), 29·795. Thermometer, dry, 59°·1; wet, 58°·6. Wind, No. 2. Elastic force of vapour, ·486. Humidity, 1·000. Weight of cubic foot of air, 530·1 grs. To ascertain the initial velocity of 9-pr. shot fired from 9-pr. field gun.

		lbs. oz.			lbs. oz.		°	°	ft.	ft.	yds.	
XVI. 1	9-pr. brass gun, No. 422. Weight, 13 cwt. 3 qrs. 18 lbs. Calibre, .	2 8	9-pr. solid shot.	—	9 $5\frac{3}{4}$	Not observed.	48·75	97·80	1575·7		354·0	Gun laid horizontal every round. Height of axis, 3′ 11″·5.
2		,, ,,		—	,, ,,		48·70	98·45	1554·5		287	
3		,, ,,		—	,, ,,		48·70	98·45	1554·5		356	
4		,, ,,		—	,, ,,		48·70	99·50	1521·2		259	
5		,, ,,		—	,, ,,		48·50	98·25	1560·9	1613·7 Mean 1563·9	290	
6		,, ,,		—	,, ,,		48·45	98·05	1567·5		303	
7		,, ,,		—	,, ,,		48·60	98·25	1560·9		265	
8		,, ,,		—	,, ,,		48·75	98·15	1564·2		357	
9		,, ,,		—	,, ,,		48·70	98·50	1552·8		277	
10		,, ,,		—	,, ,,		48·45	96·30	1626·9		250	

Same date and circumstances as 9-pr. To ascertain the initial velocity of 6-pr. solid shot fired from 6-pr. field gun.

		lbs. oz.			lbs. oz.		°	°	ft.	ft.	yds.	
XVII. 1	6-pr. brass gun, No. 1,915. Weight, 5 cwt. 2 qrs. 24 lbs. Calibre, .	1 8	6-pr. solid shot.	—	6 $8\frac{3}{4}$	Not observed.	48·40	101·55	1457·8		330	Laid accurately by spirit level. Height of axis, 3′ 9″·8.
2		,, ,,		—	,, ,,		48·30	102·20	1439·1		267	
3		,, ,,		—	,, ,,		48·55	101·55	1457·8		278	
4		,, ,,		—	,, ,,		48·60	101·90	1447·7		275	
5		,, ,,		—	,, ,,		48·70	103·55	1401·7	1484·5 Mean 1435·3	297	
6		,, ,,		—	,, ,,		48·75	101·45	1460·7		293	
7		,, ,,		—	,, ,,		48·60	103·70	1397·7		236	
8		,, ,,		—	,, ,,		48·50	102·35	1434·8		290	
9		,, ,,		—	,, ,,		48·50	102·55	1429·2		325	
10		,, ,,		—	,, ,,		48·70	102·65	1426·4		329	

To ascertain the initial velocity of shell fired from 12-pr. brass howitzer.

		lbs. oz.			lbs. oz.		°	°	ft.	ft.	yds.	
XVIII. 1	12-pr. brass gun, No. 2. Weight, 6 cwt. 2 qrs. 16 lbs. Calibre, .	1 4	12-pr. shell.	8 12	8 12	Not observed.	48·45	115·55	1125·4		248	Gun laid horizontal every round. Height of axis, 3′ 9″.
2		,, ,,		,, ,,	,, ,,		48·50	—	—		212	
3		,, ,,		,, ,,	,, ,,		48·45	116·10	1114·8		240	
4		,, ,,		,, ,,	,, ,,		48·70	112·70	1182·7		240	
5		,, ,,		,, ,,	,, ,,		48·60	114·80	1140·1	1163·4 Mean 1124·2	205	
6		,, ,,		,, ,,	,, ,,		48·40	115·75	1121·5		208	
7		,, ,,		,, ,,	,, ,,		48·35	115·20	1132·2		199	
8		,, ,,		,, ,,	,, ,,		48·35	116·70	1103·3		198	
9		,, ,,		,, ,,	,, ,,		48·40	114·60	1146·1		275	
10		,, ,,		,, ,,	,, ,,		48·50	119·50	1051·8		211	

September 17, 1860.—Barometer (32°), 29·795. Thermometer, dry, 59°·11. Thermometer, wet, 58°·6. Wind, No. 2, . Elastic force of vapour, ·486. Humidity, 1·00. Weight of cubic foot of air, 530·1. To ascertain the initial velocity of 24-pr. shell fired from 24-pr. howitzer service charges.

No. of Rounds.	Nature of Ordnance.	Charge.	Projectile. Nature.	Projectile. Diameter.	Projectile. Weight.	Recoil.	Reading of Needle. Disjunctor.	Reading of Needle. Projectile.	Velocity. At 30 yds.	Velocity. Initial.	Range.	Remarks.
		lbs. oz.			lbs. oz.		°	°	ft.	ft.	yds.	
XIX. 1	24-pr. Howitzer. No. 120. Weight 12 cwt. 3 qrs. 5 lbs. Calibre .	2 8	24-pr. common shell.	—	16 11½	Not observed.	48·65	110·55	1231·8		330	Gun laid horizontal with spirit level every round. Height of axis 4′ 0″. Powder L.G. All the cartridges out of the same barrel.
2		„ „		—	„ „		48·65	110·55	1231·8		205	
3		„ „		—	„ „		48·40	110·45	1234·0		197	
4		„ „		—	„ „		—	—	—		236	
5		„ „		—	„ „		48·55	111·00	1221·9	1252·7 Mean 1218·0	203	
6		„ „		—	„ „		48·70	112·25	1219·7		203	
7		„ „		—	„ „		48·65	110·40	1195·0		204	
8		„ „		—	„ „		48·65	113·20	1235·1		202	
9		„ „		—	„ „		—	—	—		202	
10		„ „		—	„ „		48·70	111·10	1175·1		250	

March 17, 1861.—Barometer (32°), 29·705. Thermometer, dry, 41°·0; wet 40°·8. Wind calm. Elastic force of vapour, ·259. Humidity, 1·00. Weight of cubic foot of air, 538·4 grs. To ascertain the initial velocities of the wall piece and of the Enfield rifle.

No. of Rounds.	Nature of Ordnance.	Charge.	Projectile. Nature.	Projectile. Diameter.	Projectile. Weight.	Recoil.	Reading of Needle. Disjunctor.	Reading of Needle. Projectile.	Velocity. At 30 yds.	Velocity. Initial.	Range.	Remarks.
		grs.			lbs. oz.		°	°	ft.	ft.		
XX. 1	Wall piece. Weight . . Calibre	8 0	Iron ball coated with lead.	0·935	0 5·25	—	n.o.	—	—		Not observed.	
2		„ „		„	„ „	—	30·85	97·10	1123·3			
3		„ „		„	„ „	—	30·75	95·89	1145·6			
4		„ „		„	„ „	—	—	*	—	1167·6 Mean 1134·8		
5		„ „		„	„ „	—	30·80	97·35	1119·1			
6		„ „		„	„ „	—	30·70	95·65	1148·2			
7		„ „		„	„ „	—	30·90	96·50	1133·5			
8		„ „		„	„ „	—	30·85	96·15	1139·4			
XXI. 9	Enfield rifle weight 8lb. 8oz. cal. ·577.	2·5	Service ball.	·55	530 grs	—	30·85	94·45	1169·6	1272·8 Mean 1188·7		
10		„		„	„	—	30·95	92·15	1212·4			
11		„		„	„	—	30·95	93·65	1184·2			

March 11, 1862.—Barometer (32°), 30·415. Thermometer, dry, 46°·3; wet, 43°·0. Elastic force of vapour, ·242. Humidity, ·79. Weight of cubic foot of air, 556·5. To ascertain the initial velocity of the Armstrong 6-pr.

No. of Rounds.	Nature of Ordnance.	Charge.	Projectile. Nature.	Projectile. Diameter.	Projectile. Weight.	Recoil.	Reading of Needle. Disjunctor.	Reading of Needle. Projectile.	Velocity. At 30 yds.	Velocity. Initial.	Range.	Remarks.
		lbs. oz.			lbs. oz.		°	°	ft.	ft.	yds.	
XXII. 1	6-pr. Armstrong. No. 476. 3¼ cwt. Calibre 2·500.	0 12	Segment shell.	2·585	6 0	3′ 3″	45·55	122·95	960·6		320·9	* Vent piece blew out. Ranges very carelessly taken, entitled to no confidence. Slope of platform 2° 40′. Height of axis 4 ft. 2 ins. Travelling carriage. Powder A 4, W.A., 5/9/60. Lot 288.
2		„ „		„	„ „	n.o.	45·75	—	—		271·5	
3		„ „		„	„ „	3 10	35·25	—	—		254·8	
4		„ „		„	„ „	3 3	35·45	115·55	925·4		202·3	
5		„ „		„	„ „	3 3	35·45	114·00	946·1		204·0	
6		„ „		„	„ „	3 3	35·55	115·75	922·7		203·3	
7		„ „		„	„ „	4 0	35·50	116·20	916·8	946·4	342·6	
8		„ „		„	„ „	n.o.	35·55	132·70*	—	Mean	279·5	
9		„ „		„	„ „	3 11	35·45	115·90	920·8	937·5	251·9	
10		„ „		„	„ „	3 9	35·00	113·70	944·1		—	
11		„ „		„	„ „	3 6	35·45	113·95	946·8		246·8	
12		„ „		„	„ „	3 6	37·50	116·30	943·0		204·8	
13		„ „		„	„ „	3 6	37·45	115·90	948·6		248·3	
14		„ „		„	„ „	4 0	37·75	116·40	941·6		230·0	
15		„ „		„	„ „	4 0	37·55	116·25	943·7		231·6	

September 11, 1860.—Barometer (32°), 30·370. Thermometer (dry), { 59°·2. Wet 49°·9. / 54°·5. „ 49°·0. } Elastic force of vapour, ·239. Humidity, ·48. Weight of cubic foot of air, 541·6. To ascertain the initial velocity of the Armstrong 12-pr. segment shell.

No. of Rounds.	Nature of Ordnance.	Charge.	Projectile. Nature.	Projectile. Diameter.	Projectile. Weight.	Recoil.	Reading of Needle. Disjunctor.	Reading of Needle. Projectile.	Velocity. At 30 yds.	Velocity. Initial.	Range.	Remarks.
		lbs. oz.			lbs. oz.		°	°	ft.	ft.	yds.	
XXIII. 1	12-pr. Armstrong. No. 224. Weight 8 cwt. 2 qrs. 19 lbs.	1 8	Segment shell.	3·085	11 9	Not observed.	42·80	107·25	1184·2		324	Gun No. 224. Laid point blank. Powder A 4.
2		„ „		3·085	„ „		42·95	107·40	1181·2		312	
3		„ „		3·084	„ „		42·90	107·75	1174·3		320	
4		„ „		3·083	„ „		42·75	107·55	1182·1		310	
5		„ „		3·083	„ „		42·70	106·80	1193·2	1190·2 Mean 1180·9	332	
6		„ „		3·084	„ „		42·80	106·85	1192·2		334	
7		„ „		3·085	„ „		42·90	107·50	1179·2		310	
8		„ „		3·085	„ „		42·75	—			359	
9		„ „		3·084	„ „		42·90	107·95	1170·4		303	
10		„ „		3·084	„ „		42·90	107·90	1171·4		304	

Aug. 28, 1860.—Preliminary Experiments to ascertain the Working of the Instrument.

No. of Rounds.	Nature of Ordnance.	Charge.	Projectile. Nature.	Projectile. Diameter.	Projectile. Weight.	Recoil.	Reading of Needle. Disjunctor.	Reading of Needle. Projectile.	Velocity. At 30 yds.	Velocity. Initial.	Range.	REMARKS.
		lbs. oz.			lbs. oz.		°	°	ft.	ft.	yds.	
XXIV. 1	Armstrong, 12-pr., No. 224. Weight, 8 cwt. 2 qrs. 19 lbs.	1 8	12-pr. segment shell, weighted with sand.	3·084	10 14½	Not observed.	42·75	—	1188·9	1197·4 Mean 1187·5		Gun had during the first 7 rounds a slight depression, laid by spirit level the rest of the day. Chamber washed out after every round.
2		,, ,,		,,	,, ,,		42·80	105·85	1189·1			
3		,, ,,		,,	,, ,,		42·55	105·80	1189·1			
4		,, ,,		,,	,, ,,		42·50	105·80	1201·1			
5		,, ,,		,,	,, ,,		42·65	105·20	1181·2			
6		,, ,,		,,	,, ,,		42·65	106·20	1187·1			
7		,, ,,		,,	,, ,,		42·70	105·90	1203·1			
8		,, ,,		,,	,, ,,		42·79	105·05	1188·1			
9		,, ,,		,,	,, ,,		42·60	105·80	—			
10		,, ,,		,,	,, ,,		42·60	—	—			
11		,, ,,		,,	,, ,,		42·55	—	—			
12		,, ,,		,,	,, ,,		42·55	106·30	1178·3			
13		,, ,,		,,	,, ,,		42·56	106·60	1192·0			
14		,, ,,		,,	,, ,,		42·55	106·30	1178·3			
15		,, ,,		,,	,, ,,		42·55	106·45	1175·4			
16		,, ,,		,,	,, ,,		42·55	105·75	1189·1			
17		,, ,,		,,	,, ,,		42·65	106·40	1176·3			
18		,, ,,		,,	,, ,,		42·60	105·80	1188·1			
19		,, ,,		,,	,, ,,		42·75	105·65	1190·6			
20		,, ,,		,,	,, ,,		42·60	105·65	1190·6			
21		,, ,,		,,	,, ,,		42·70	105·80	1188·1			

September 1, 1860.—Barometer (32°), 30·060. Thermometer, dry, 64°·5; wet, 59°·0. Wind light. Elastic force of vapour, ·427. Humidity, ·70. Weight of cubic foot of air, 529·6 grs. To ascertain the initial velocity in function of the weight of the shot.

No. of Rounds.	Nature of Ordnance.	Charge.	Projectile. Nature.	Projectile. Diameter.	Projectile. Weight.	Recoil.	Reading of Needle. Disjunctor.	Reading of Needle. Projectile.	Velocity. At 30 yds.	Velocity. Initial.	Range.	REMARKS.
		lbs. oz.			lbs. oz.		°	°	ft.	ft.	yds.	
XXV. 1	Armstrong 12-pr., No. 224. Weight, 8 cwt. 2 qrs. 19 lbs.	1 8	12-pr. segment shell, weighted with buck shot.	3·083	11 13	Not observed.	42·90	—	—	1190·6 Mean 1181 5	—	Gun laid perfectly horizontal every round. * Shell stripped. † Doubtful. After this experiment was completed, it was found that two kinds of powder had been supplied; and this fact accounts for the discrepancies which may be observed in this series. ‡ Fired too soon. § Signal mistaken.
2		,, ,,		3·083	,, ,,		42·90	107·75	1179·2		324	
3		,, ,,		3·083	,, ,,		42·90	107·20	1186·12		329	
4		,, ,,		3·083	,, ,,		42·95	106·60	1198·2		335	
5		,, ,,		3·082	,, ,,		42·95	107·65	1177·2		315	
6		,, ,,		3·083	,, ,,		42·90	107·15	1187·1		327	
7		,, ,,		3·083	,, ,,		42·95	108·25	1165·5		327	
8		,, ,,		3·085	,, ,,		42·90	107·40	1182·2		311	
9		,, ,,		3·083	,, ,,		42·90	106·95	1191·2		322	
10		,, ,,		3·083	,, ,,		42·85	107·70	1176·2		301	
11		,, ,,		3·083	,, ,,		42·85	107·90	1172·3		300	
XXVI. 12		,, ,,		3·082	11 9		42·85	106·95	1189·6	1204·8 Mean 1195·4	321	
13		,, ,,		3·083	,, ,,		42·85	106·60	1195·4		326	
14		,, ,,		3·083	,, ,,		42·80	106·10	1206·8		330	
15		,, ,,		3·084	,, ,,		42·85	106·75	1193·6		326	
16		,, ,,		3·085	,, ,,		42·75	106·85	1191·6		321	
XXVII. 17		,, ,,		3·083	11 5		42·85	106·40	1200·6	1200·4 Mean 1190·8	—	
18		,, ,,		3·089	,, ,,		42·85	*119·70	1180·6		—	
19		,, ,,		3·084	,, ,,		42·75	107·40	1181·6		296†	
20		,, ,,		3·083	,, ,,		42·85	107·35	1207·8		323	
21		,, ,,		3·083	,, ,,		42·80	106·05	1183·6		311	
22		,, ,,		3·084	,, ,,		42·95	107·25	—		323	
XXVIII. 23		,, ,,		3·082	11 1		‡ —	—	—	1215·6 Mean 1205·6	—	
24		,, ,,		3·085	,, ,,		42·75	104·90	1230·5		352	
25		,, ,,		3·083	,, ,,		42·85	106·60	1196·6		325	
26		,, ,,		3·085	,, ,,		42·80	106·40	1200·6		307	
27		,, ,,		3·083	,, ,,		42·80	§ —	—		316	
28		,, ,,		3·083	,, ,,		42·75	106·20	1204·7		317	
29		,, ,,		3·083	,, ,,		42·85	106·65	1195·4		311	

September 3, 1860.—Barometer (32°), 30·210. Thermometer (dry), 62°·4; (wet) 54°·8. Wind light. Elastic force of vapour, ·331. Humidity, ·59. Weight of cubic foot of air, 558·1 grs. To ascertain the initial velocity as a function of the weight of the shot.

No. of Rounds	Nature of Ordnance.	Charge.	Projectile. Nature.	Projectile. Diameter.	Projectile. Weight.	Recoil.	Reading of Needle. Disjunctor.	Reading of Needle. Projector.	Velocity. At 30 yds.	Velocity. Initial.	Range.	Remarks.
		lbs. oz.			lbs. oz.		°	°	ft.	ft.	yds.	
XXIX. 1	Armstrong 12-pr., No. 224. Weight, 8 cwt. 2 qrs. 19 lbs.	1	12-pr. segment shell weighted with buck shot.	3·085	11 13		42·80	107·30	1182·9	1173·4 Mean 1164·5	—	Gun laid P. B. by spirit level every round. Chamber washed out after every round. * Shell stripped.
2		,, ,,		3·085	,, ,,		42·80	108·20	1169·3		—	
3		,, ,,		3·083	,, ,,		42·75	108·15	1166·3		310	
4		,, ,,		3·085	,, ,,		42·80	108·25	1164·3		324	
5		,, ,,		3·083	,, ,,		42·90	108·45	1160·4		313	
6		,, ,,		3·084	,, ,,		42·90	108·05	1168·2		323	
7		,, ,,		3·085	,, ,,		42·75	108·75	1154·7		323	
8		,, ,,		3·083	,, ,,		42·85	108·25	1164·3		316	
9		,, ,,		3·083	,, ,,		42·95	108·10	1167·2		324	
10		,, ,,		3·084	,, ,,		42·90	108·35	1162·3		314	
11		,, ,,		3·085	,, ,,		—	107·85	1172·1		324	
XXX. 12		,, ,,		3·084	11 5		43·05	107·10	1189·6	1202·5 Mean 1192·9	324	
13		,, ,,		3·085	,, ,,		43·00	107·55	1180·6		310	
14		,, ,,		3·085	,, ,,		42·90	106·65	1198·6		315	
15		,, ,,		3·083	,, ,,		43·00	106·40	1202·5		300	
16		,, ,,		3·084	,, ,,		42·95	106·05	1210·8		320	
17		,, ,,		3·083	,, ,,		42·95	106·70	1197·6		336	
18		,, ,,		3·085	,, ,,		42·95	*107·55	1180·6		301	
19		,, ,,		3·084	,, ,,		43·00	106·05	1210·8		370	
20		,, ,,		3·084	,, ,,		—	107·20	1187·5		314	
21		,, ,,		3·085	,, ,,		—	107·60	1179·6		300	
22		,, ,,		3·085	,, ,,		—	107·40	1183·5		300	
XXXI. 23		,, ,,		3·085	10 13		42·90	105·90	1212·8	1220·1 Mean 1209·8	292	
24		,, ,,		3·083	,, ,,		43·00	105·80	1214·8		—	
25		,, ,,		3·083	,, ,,		42·95	106·40	1202·5		288	
26		,, ,,		3·084	,, ,,		42·95	106·75	1195·4		293	
27		,, ,,		3·083	,, ,,		42·90	106·50	1200·4		319	
28		,, ,,		3·084	,, ,,		42·85	105·85	1213·8		320	
29		,, ,,		3·083	,, ,,		42·85	106·00	1210·7		319	
30		,, ,,		3·083	,, ,,		42·80	105·85	1213·8		—	
31		,, ,,		3·083	,, ,,		43·00	105·40	1223·2		314	
32		,, ,,		3·084	,, ,,		42·95	106·00	1210·7		292	

September 5, 1860.—Barometer (32°) 30·335. Thermometer (dry) 61°·5; wet, 57°·4. Elastic force of vapour, ·420. Humidity, ·77. Weight of cubic foot of air, 537·6 grs. To ascertain the initial velocity of an Armstrong shell in function of the weight of the charge.

No. of Rounds	Nature of Ordnance.	Charge.	Projectile. Nature.	Projectile. Diameter.	Projectile. Weight.	Recoil.	Reading of Needle. Disjunctor.	Reading of Needle. Projector.	Velocity. At 30 yds.	Velocity. Initial.	Range.	Remarks.
		lbs. oz.			lbs. oz.		°	°	ft.	ft.	yds.	
XXXII. 1	Armstrong, 12-pr., No. 224. Weight, 8 cwt. 2 qrs. 19 lbs.	1 4	12-pr. segment shell, weighted with buck shot.	3·084	11 9		42·60	112·70	1080·2	1063·1 Mean 1055·3	276·0	Gun laid P.B. every round. Chamber washed out after every round.
2		,, ,,		3·085	,, ,,		42·55	113·40	1068·1		277·0	
3		,, ,,		3·085	,, ,,		42·60	112·90	1076·7		277·0	
4		,, ,,		3·085	,, ,,		42·75	113·70	1063·0		276·0	
5		,, ,,		3·084	,, ,,		42·75	114·55	1048·6		264·0	
6		,, ,,		3·083	,, ,,		42·75	114·00	1058·0		265·0	
7		,, ,,		3·083	,, ,,		42·75	115·50	1033·0		256·0	
8		,, ,,		3·085	,, ,,		42·75	114·35	1052·0		264·0	
9		,, ,,		3·083	,, ,,		42·65	114·20	1054·6		264·0	
10		,, ,,		3·085	,, ,,		42·85	116·35	1019·0		256·0	
XXXIII. 11		1 6		3·085	,, ,,		42·75	110·65	1118·4	1100·7 Mean 1092·4	296·0	
12		,, ,,		3·085	,, ,,		42·85	112·50	1085·4		265·0	
13		,, ,,		3·085	,, ,,		42·80	113·40	1069·9		265·0	
14		,, ,,		3·084	,, ,,		42·80	111·25	1107·5		305·0	
15		,, ,,		3·085	,, ,,		42·75	112·85	1079·2		279·0	
16		,, ,,		3·085	,, ,,		42·85	113·40	1069·9		270·0	
17		,, ,,		3·084	,, ,,		42·80	110·65	1118·4		296·0	
18		,, ,,		3·085	,, ,,		42·85	110·50	1121·2		280·0	
19		,, ,,		3·085	,, ,,		43·25	113·40	1077·2		249·0	
20		,, ,,		3·084	,, ,,		43·20	113·40	1077·2		298·0	

September 11, 1860.—Barometer (32°), 30·370. Thermometer, dry { 59°·2 wet 49°·9 / 54°·5 „ 49°·0 } Wind, No. 2, Up range. Elastic force of vapour, ·239. Humidity, ·48. Weight of cubic foot of air, 541·56 grains. To ascertain the initial velocity of the Armstrong 12-pr. shell in function of the weight of the charge.—*continued.*

Series	No. of Rounds.	Nature of Ordnance.	Charge.	Projectile. Nature.	Projectile. Diameter.	Projectile. Weight.	Recoil.	Reading of Needle. Disjunctor.	Reading of Needle. Projectile.	Velocity. At 30 yds.	Velocity. Initial.	Range.	REMARKS.
			lbs. oz.			lbs. oz.		°	°	ft.	ft.	yds.	
XXXIV.	21	Armstrong 12-pr., No. 224, weight 8 cwt. 2 qrs. 19 lbs.	1 8	12-pr. segment shell, loaded with buck shot.	3·085	11 9	—	42·80	107·25	1184·2	1190·2 Mean 1180·9	324	Gun laid horizontal by spirit level and chamber sponged out with a wet sponge after every round. Gun mounted on travelling carriage. Height of axis.
	22		„ „		3·085	„ „	—	42·95	107·40	1181·2		312	
	23		„ „		3·084	„ „	—	42·90	107·75	1174·3		320	
	24		„ „		3·083	„ „	—	42·75	107·35	1182·1		310	
	25		„ „		3·083	„ „	—	42·70	106·80	1193·2		332	
	26		„ „		3·084	„ „	—	42·80	106·85	1192·2		334	
	27		„ „		3·085	„ „	—	42·90	107·50	1179·2		310	
	28		„ „		3·085	„ „	—	42·75	—	—		359	
	29		„ „		3·084	„ „	—	42·90	107·95	1170·4		303	
	30		„ „		3·084	„ „	—	42·90	107·90	1171·4		304	
XXXV.	31		1 10		3·084	„ „	—	42·85	105·65	1216·6	1234·6 Mean 1224·8	348	
	32		„ „		3·085	„ „	—	42·75	105·75	1214·6		332	
	33		„ „		3·085	„ „	—	42·95	105·00	1230·3		310	
	34		„ „		3·083	„ „	—	42·90	105·35	1223·0		359	
	35		„ „		3·084	„ „	—	42·95	105·45	1220·8		340	
	36		„ „		3·083	„ „	—	42·85	106·05	1208·4		348	
	37		„ „		3·084	„ „	—	42·80	105·05	1229·2		352	
	38		„ „		3·086	„ „	—	43·05	105·00	1236·7		355	
	39		„ „		3·085	„ „	—	43·05	105·15	1233·5		332	
	40		„ „		3·084	„ „	—	43·15	105·10	1234·5		335	
XXXVI.	41		1 12		3·084	„ „	—	43·25	104·40	1249·9	1272·2 Mean 1262·0	355	
	42		„ „		3·084	„ „	—	43·25	104·55	1246·7		360	
	43		„ „		3·085	„ „	—	—	104·40	1249·9		336	
	44		„ „		3·083	„ „	—	43·10	104·15	1255·5		336	
	45		„ „		3·083	„ „	—	43·25	103·35	1273·0		339	
	46		„ „		3·085	„ „	—	43·25	102·95	1282·0		388	
	47		„ „		3·085	„ „	—	43·30	102·95	1282·0		344	
	48		„ „		3·085	„ „	—	43·35	104·15	1255·5		345	
	49		„ „		3·085	„ „	—	43·40	104·20	1254·1		354	
	50		„ „		3·085	„ „	—	43·30	103·40	1271·9		325	

March 12, 1861.—Barometer (32°), 29·520. Thermometer, dry, 45°·0; wet, 43°·1. Elastic force of vapour, ·251. Humidity, ·84. Weight of cubic foot of air, 541·4 grains. To ascertain the velocity of the Armstrong 12-pr. shell, in function of the weight of the charge.—2nd series.

Series	No. of Rounds.	Nature of Ordnance.	Charge.	Projectile. Nature.	Projectile. Diameter.	Projectile. Weight.	Recoil.	Reading of Needle. Disjunctor.	Reading of Needle. Projectile.	Velocity. At 30 yds.	Velocity. Initial.	Range.	REMARKS.
			lbs. oz.			lbs. oz.		°	°	ft.	ft.	yds.	
XXXVII.	1	Armstrong 12-pr., No. 1050, weight 8 cwt. 2 qrs. 18 lbs.	0 14	12-pr. segment shell, with the weight made up with buck shot.	3·084	11 9	5 10	33·45	—	—	809·2 Mean 803·8	203·9	Lubricating wads made up in the cartridge were used throughout this experiment. It was found, however, that with the low charges the wad did not break up, and it was necessary to sponge the gun. This practice was continued throughout the experiment. Gun mounted on travelling carriage, height of axis 4 feet 3 inches, slope of platform 1°. The platform was wet and slippery, and there were occasional heavy showers of rain throughout the day. Powder, A 4. W. A. 5/9/60. Lot 288. * Shell stripped.
	2		„ „		„	„ „	6 0	33·45	123·45	806·1		231·1	
	3		„ „		„	„ „	6 0	33·40	123·15	809·4		204·5	
	4		„ „		„	„ „	6 6	33·40	123·45	806·1		205·0	
	5		„ „		„	„ „	6 6	33·45	123·30	807·7		204·4	
	6		„ „		„	„ „	6 6	33·35	123·85	801·6		203·1	
	7		„ „		„	„ „	7 2	33·50	124·05	799·4			
	8		„ „		„	„ „	6 5	33·35	—	—		183·0	
	9		„ „		„	„ „	7 1	33·30	124·30	796·6		200·8	
	10		„ „		„	„ „	7 0	33·05	—	—		248·7	
XXXVIII.	11		1 0		„	„ „	8 0	—	—	—	870·0 Mean 863·9	232·5	
	12		„ „		„	„ „	8 1	32·90	120·25*	835·8		188·3	
	13		„ „		„	„ „	8 7	32·80	118·45	856·6		163·0	
	14		„ „		„	„ „	9 1	32·70	118·30	858·4		163·0	
	15		„ „		„	„ „	9 3	32·75	118·30	858·4		163·3	
	16		„ „		„	„ „	9 4	32·75	120·35*	835·		166·5	
	17		„ „		„	„ „	10 5	32·80	117·10	872·6		170·3	
	18		„ „		„	„ „	10 6	32·75	117·05	873·2		171·	
	19		„ „		„	„ „	11 8	32·70	117·40	869·0		171·1	
	20		„ „		„	„ „	11 0	32·75	118·25	859·0		100·3	
XXXIX.	21		1 2		„	„ „	11 6	38·25	117·25	940·2	931·1 Mean 924·6	203·3	
	22		„ „		„	„ „	13 3	38·40	119·00	916·2		181·3	
	23		„ „		„	„ „	12 6	38·40	123·15*	861·9		247·0	
	24		„ „		„	„ „	11 9	38·35	119·75	906·1		181·5	
	25		„ „		„	„ „	11 6	40·00	120·85*	909·6		203·3	
	26		„ „		„	„ „	11 9	39·80	—	—		202·3	
	27		„ „		„	„ „	11 6	39·75	119·05	934·6		237·3	
	28		„ „		„	„ „	9 6	39·75	118·75	938·8		201·0	
	29		„ „		„	„ „	9 6	39·90	120·90	909·0		197·5	
	30		„ „		„	„ „	9 6	40·00	119·55	927·6		199·1	

March 12, 1861.—Barometer (32°), 29·520. Thermometer, dry, 45°·0; wet, 43°·1. Elastic force of vapour, ·251. Humidity, ·84. Weight of cubic foot of air, 541·4 grains. To ascertain the velocity of the Armstrong 12-pr. shell in function of the weight of the charge.—*continued.*

	No. of Rounds.	Nature of Ordnance.	Charge.	Projectile. Nature.	Projectile. Diameter.	Projectile. Weight.	Recoil.	Reading of Needle. Disjunctor.	Reading of Needle. Projector.	Velocity. At 30 yds.	Velocity. Initial.	Range.	Remarks.
			lbs. oz.		3·084	lbs. oz.		°	°	ft.	ft.	yds.	
XL.	31	Armstrong 12-pr., No. 1050, weight 8 cwt. 2 qrs. 18 lbs.	1 4	12-pr. segment shell, with the weight made up with buck shot.	,,	11 9	10 3	39·80	114·80	996·7	1005·1 Mean 997·8	204·0	
	32		,, ,,		,,	,, ,,	11 6	39·80	115·50	986·1		206·8	
	33		,, ,,		,,	,, ,,	13 6	39·85	114·75	997·5		211·1	
	34		,, ,,		,,	,, ,,	12 9	39·00	113·55	1005·6		210·0	
	35		,, ,,		,,	,, ,,	13 3	39·10	114·15	996·5		200·7	
	36		,, ,,		,,	,, ,,	13 6	39·20	115·05	983·1		210·5	
	37		,, ,,		,,	,, ,,	13 4	39·20	113·20	1011·0		210·3	
	38		,, ,,		,,	,, ,,	13 3	39·30	114·10	997·3		204·9	
	39		,, ,,		,,	,, ,,	12 9	39·15	114·10	997·3		203·7	
	40		,, ,,		,,	,, ,,	13 0	39·25	113·45	1007·2		211·1	
XLI.	41		1 6		,,	,, ,,	14 0	39·15	111·20	1042·4	1058·0 Mean 1050·2	235·6	
	42		,, ,,		,,	,, ,,	13 9	39·25	111·15	1043·2		236·0	
	43		,, ,,		,,	,, ,,	14 9	39·20	110·05	1061·1		235·3	
	44		,, ,,		,,	,, ,,	15 3	39·15	110·55	1052·9		240·9	
	45		,, ,,		,,	,, ,,	14 9	39·10	110·20	1058·6		244·3	
	46		,, ,,		,,	,, ,,	14 8	39·10	110·30	1057·0		246·5	
	47		,, ,,		,,	,, ,,	15 8	39·00	110·75	1049·7		245·6	
	48		,, ,,		,,	,, ,,	14 9	39·15	110·75	1049·7		245·3	
	49		,, ,,		,,	,, ,,	15 3	39·20	110·30	1057·0		245·5	
	50		,, ,,		,,	,, ,,	15 6	39·40	111·95	1030·5		240·6	
XLII.	51		1 8		,,	,, ,,	16 0	40·40	110·07	1081·4	1114·8 Mean 1106·4	252·0	
	52		,, ,,		,,	,, ,,	16 9	42·75	112·00	1087·7		267·0	
	53		,, ,,		,,	,, ,,	16 0	37·15*	104·79	1117·8		264·6	* Changed conjunctor, it being out of order.
	54		,, ,,		,,	,, ,,	16 0	37·30	106·00	1096·3		251·0	
	55		,, ,,		,,	,, ,,	—	37·10	105·09	1112·6		250·0	
	56		,, ,,		,,	,, ,,	—	37·20	104·30	1125·8		253·0	
	57		,, ,,		,,	,, ,,	—	37·25	105·15	1110·9		250·6	
	58		,, ,,		,,	,, ,,	—	37·35	105·10	1111·8		252·6	
	59		,, ,,		,,	,, ,,	—	37·30	105·45	1105·7		246·6	
	60		,, ,,		,,	,, ,,	—	37·20	105·00	1113·5		246·0	
XLIII.	61		1 10		,,	,, ,,	—	37·45	101·75	1172·3	1187·3 Mean 1178·0	314·0	
	62		,, ,,		,,	,, ,,	—	37·35	100·90	1188·6		298·4	
	63		,, ,,		,,	,, ,,	—	37·10	100·75	1191·4		277·0	
	64		,, ,,		,,	,, ,,	—	37·35	101·40	1178·9		287·1	
	65		,, ,,		,,	,, ,,	—	37·45	101·85	1170·4		321·6	
	66		,, ,,		,,	,, ,,	—	37·50	101·95	1168·6		387·6†	† Doubtful.
	67		,, ,,		,,	,, ,,	—	36·60	102·35	1150·7		—	13th March 1861.
	68		,, ,,		,,	,, ,,	—	36·65	—	—		—	
	69		,, ,,		,,	,, ,,	—	36·80	100·35	1188·2		—	
	70		,, ,,		,,	,, ,,	—	36·75	100·10	1193·0		—	

September 14, 1860.—Barometer (32°), 29·750. Thermometer, dry { 60°·1; wet 51°·6 / 58°·7 ,, 50°·5 } Wind, No. 3, Up Range. Elastic force of vapour, ·270. Humidity, ·52. Weight of cubic foot of air, 529·6 grains. To ascertain the difference between the initial velocity of high and low gauge 12-pr. shot.

	No. of Rounds.	Nature of Ordnance.	Charge.	Projectile. Nature.	Projectile. Diameter.	Projectile. Weight.	Recoil.	Disjunctor.	Projector.	At 30 yds.	Initial.	Range.	Remarks.
			lbs. oz.			lbs. oz.		°	°	ft.	ft.	yds.	
XLIV.	1	Armstrong 12-pr., No. 224, weight 8 cwt. 2 qrs. 18 lbs.	1 8	12-pr. segment shell, weight made up with shot.	3·080	11 9	Not observed.	42·70	106·85	1193·2	1193·4 Mean 1184·1	311	Low gauge; bore washed.
	2		,, ,,		3·078	,, ,,		42·90	106·95	1191·1		320	
	3		,, ,,		3·079	,, ,,		42·65	107·50	1180·1		331	
	4		,, ,,		3·080	,, ,,		42·90	107·75	1175·2		336	
	5		,, ,,		3·080	,, ,,		42·85	107·45	1181·1		340	
XLV.	6		,, ,,		3·085	,, ,,		42·90	—	—	1186·5 Mean 1177·2	313	High gauge; bore washed.
	7		,, ,,		3·085	,, ,,		42·95	108·24	1165·4		320	
	8		,, ,,		3·085	,, ,,		43·00	107·60	1178·3		292	
	9		,, ,,		3·085	,, ,,		43·00	107·65	1177·2		315	
	10		,, ,,		3·083	,, ,,		42·95	106·70	1176·2		313	
	11		,, ,,		3·085	,, ,,		43·10	107·05	1189·1		320	
XLVI.	12		,, ,,		3·080	,, ,,		43·15	107·50	1183·8	1193·4 Mean 1184·1	320	Lubricating wads; low gauge.
	13		,, ,,		3·079	,, ,,		43·15	107·90	1175·8		320	
	14		,, ,,		3·080	,, ,,		43·05	107·50	1183·8		314	
	15		,, ,,		3·079	,, ,,		43·05	107·25	1188·8		320	
	16		,, ,,		3·080	,, ,,		43·05	108·25	1168·9		324	
	17		,, ,,		3·080	,, ,,		43·05	106·30	1208·1		332	
	18		,, ,,		3·080	,, ,,		43·00	108·70	1160·2		333	
	19		,, ,,		3·079	,, ,,		42·95	106·90	1195·8		323	
	20		,, ,,		3·080	,, ,,		42·95	107·10	1191·8		313	

September 14, 1860.—Barometer (32°), 29·750. Thermometer, dry, { 60°·1 / 58°·7 }; wet, { 51°·6 / „ 50°·5 } Wind, No. 3. Elastic force of vapour, 270. Humidity, ·52. Weight of cubic foot of air, 529·6 grains. To ascertain the difference between the initial velocity of high and low gauge 12-pr. projectiles, and also the effect of lubricating wads—*continued.*

No. of Rounds.	Nature of Ordnance.	Charge.	Projectile. Nature.	Projectile. Diameter.	Projectile. Weight.	Recoil.	Reading of Needle. Disjunctor.	Reading of Needle. Projector.	Velocity. At 30 yds.	Velocity. Initial.	Range.	REMARKS.
		lbs. oz.			lbs. oz.				ft.	ft.	yds.	
XLVII. 21	Armstrong 12-pr. No. 220.	1 8	Segment shell.	3·085	11 9	Not observed.	43·15	107·40	1185·8		337	High gauge, lubricating wads.
22		„ „		3·083	„ „		43·10	106·45	1205·0		351	
23		„ „		3·084	„ „		43·15	107·10	1191·8		334	
24		„ „		3·085	„ „		43·05	107·75	1178·8	1197·1	330	
25		„ „		3·086	„ „		43·20	107·60	1181·8	Mean	329	
26		„ „		3·084	„ „		43·00	108·60	1162·2	1187·8	323	
27		„ „		3·085	„ „		43·20	106·40	1206·0		321	
28		„ „		3·086	„ „		—	107·15	1190·8		329	

October 18, 1860.—Barometer (32°), 30·050. Thermometer, dry, 56°·2; wet, 52°·0. Calm. Elastic force of vapour ·338. Humidity, ·75. Weight of cubic foot of air, 530·7 grains. To ascertain the difference between the initial velocity of old and new pattern 12-pr. shells, with and without lubricating wads.

No. of Rounds.	Nature of Ordnance.	Charge.	Projectile. Nature.	Projectile. Diameter.	Projectile. Weight.	Recoil.	Reading of Needle. Disjunctor.	Reading of Needle. Projector.	Velocity. At 30 yds.	Velocity. Initial.	Range.	REMARKS.
		lbs. oz.			lbs. oz.				ft.	ft.	yds.	
XLVIII. 1	12-pr. Armstrong, No. 224, weight, 8 cwt. 2 qrs. 18 lbs.	1 8	Segment shell wadded to weight with buck shot.	3·072	11 9	Not observed.	41·50	108·45	1136·0		290	Excluded from the mean.
2		„ „		„	„ „		41·45	107·10	1161·4		297	
3		„ „		„	„ „		41·40	—	—		318	Powder, A4., from same barrel.
4		„ „		„	„ „		41·40	107·25	1158·5		296	
5		„ „		„	„ „		41·45	107·05	1162·4		308	Q. pattern shell, with lubricating wads.
6		„ „		„	„ „		41·45	107·45	1154·7		326	
7		„ „		„	„ „		41·50	107·55	1152·8	1163·2	323	
8		„ „		„	„ „		41·55	107·40	1155·6	Mean	300	
9		„ „		„	„ „		41·60	107·79	1149·0	1154·2	306	
10		„ „		„	„ „		41·65	107·50	1153·7		300	
11		„ „		„	„ „		41·65	107·70	1149·9		303	
12		„ „		„	„ „		41·60	107·65	1150·9		300	
13		„ „		„	„ „		41·50	107·65	1150·9		310	
14		„ „		„	„ „		41·50	107·60	1151·8		323	
15		„ „		„	„ „		41·65	107·50	1153·7		316	
XLIX. 16		„ „		3·085	„ „		41·60	107·15	1160·4		323	
17		„ „		„	„ „		41·65	107·90	1146·1		295	
18		„ „		„	„ „		41·50	107·30	1157·6		267	
19		„ „		„	„ „		41·65	107·80	1148·0		326	
20		„ „		„	„ „		41·55	107·20	1159·5		330	Service pattern with lubricating wads.
21		„ „		„	„ „		41·45	107·70	1149·9		297	
22		„ „		„	„ „		—	107·50	1153·7	1166·1	324	
23		„ „		„	„ „		41·65	107·10	1161·4	Mean	300	
24		„ „		„	„ „		41·60	107·25	1158·5	1157·1	337	
25		„ „		„	„ „		41·65	106·80	1167·2		292	
26		„ „		„	„ „		41·60	105·80*	1186·7		315	* A wrong cartridge used by mistake.
27		„ „		„	„ „		41·45	108·00	1144·4		330	
28		„ „		„	„ „		41·45	106·70	1169·1		336	
29		„ „		„	„ „		41·50	106·80	1167·2		332	
L. 30		„ „		„	„ „		41·70	108·05	1146·1		302	The gun was here carefully washed out.
31		„ „		„	„ „		41·65	108·25	1142·3		293	
32		„ „		„	„ „		41·75	108·15	1144·2		294	
33		„ „		„	„ „		41·70	108·75	1133·1		278	Service pattern, bore washed out after every round. No wads.
34		„ „		„	„ „		41·75	108·10	1145·1		278	
35		„ „		„	„ „		41·75	107·75	1151·7	1150·8	300	
36		„ „		„	„ „		41·55	108·50	1137·7	Mean	288	
37		„ „		„	„ „		41·80	108·00	1147 0	1142·0	300	
38		„ „		„	„ „		41·80	—	—		—	
39		„ „		„	„ „		41·65	—	—		—	
40		„ „		„	„ „		41·55	109·00†	1128·5		290	† Doubtful.
41		„ „		„	„ „		41·65	—	—		253	
42		„ „		„	„ „		41·60	108·15	1144·2		266	
LI. 43		„ „		3·072	„ „		41·45	108·40	1135·7		250	Q. pattern. No wads.
44		„ „		„	„ „		41·40	108·25	1138·4		253	
45		„ „		„	„ „		41·40	107·65	1149·6		262	
46		„ „		„	„ „		41·45	108·45	1134·7		252	
47		„ „		„	„ „		41·55	108·05	1142·1	1149·4	252	
48		„ „		„	„ „		41·50	107·75	1147·8	Mean	270	
49		„ „		„	„ „		41·50	108·00	1143·1	1140·6	276	
50		„ „		„	„ „		41·40	108·30	1137·5		255	
51		„ „		„	„ „		41·50	108·05	1142·1		250	
52		„ „		„	„ „		41·55	108·45	1134·7		254	

March 13, 1861.—Barometer (32°), 30·075. Thermometer, dry, 43°·0; wet, 37°·0. Elastic force of vapour, ·142. Humidity, ·51. Weight of cubic foot of air, 554·5. grs. To ascertain the initial velocity of a 9-lb. shell, fired with a charge of 1 lb. 2 oz. from the 12-pr. gun.

No. of Rounds.	Nature of Ordnance.	Charge.	Projectile. Nature.	Projectile. Diameter.	Projectile. Weight.	Recoil.	Reading of Needle. Disjunctor.	Reading of Needle. Projector.	Velocity. At 30 yds.	Velocity. Initial.	Range.	REMARKS.
		lbs. oz.			lbs. oz.		°	°	ft.	ft.	yds.	
LII. 1	12-pr. Armstrong, No. 1,050.	1 2		3·074	9 0	8 4	36·85	102·90	1140·8		210·1	Gun laid p. b. with spirit level. Lubricating wads used. Powder, A 4, Hall & Sons, 11/7/60. Lot 2. * No reading. Ranges appear doubtful; probably a mistake has been made in counting the pegs. Instrument used, No.32.
2		,, ,,		,,	,, ,,	8 6	36·90	—	*		245·1	
3		,, ,,		,,	,, ,,	8 2	36·85	—	*	1141·2	252·0	
4		,, ,,		,,	,, ,,	8 1	36·85	102·85	1141·8	Mean	247·1	
5		,, ,,		,,	,, ,,	7 9	36·95	103·75	1125·7	1130·0	244·3	
6		,, ,,		,,	,, ,,	7 2	36·65	104·70	1109·1		243·0	
7		,, ,,		,,	,, ,,	6 9	36·85	103·35	1132·8		248·6	

March 13, 1861.—Barometer, (32°) 30·075. Thermometer, dry, 43°·0; wet, 37°·0. Elastic force of vapour, ·142. Humidity, ·51. Weight of cubic foot of air, 554·5 grs. To ascertain the initial velocity of projectiles fired from a 12-pr. Armstrong gun as a function of the weight of the projectile.

No. of Rounds.	Nature of Ordnance.	Charge.	Projectile. Nature.	Projectile. Diameter.	Projectile. Weight.	Recoil.	Reading of Needle. Disjunctor.	Reading of Needle. Projector.	Velocity. At 30 yds.	Velocity. Initial.	Range.	REMARKS.
		lbs. oz.			lbs. oz.		°	°	ft.	ft.	yds.	
LIII. 1	12-pr. Armstrong, No. 1,050. Weight, 8 cwt. 2 qrs. 18 lbs.	1 8	First shell.	3·074	9 0	8 5	36·70	94·00	1321·6		—	Gun laid p. b. with spirit level. Lubricating wads used. Ranges appear erroneous, and are evidently carelessly taken. Powder used, A 4, Hall and Sons, 11/7/60, Lot 2. The powder used for rounds 6 to 11 is supposed to be the same; but this is not certain.
2		,, ,,		,,	,, ,,	8 2	36·90	93·85	1328·1	1336·3	—	
3		,, ,,		,,	,, ,,	8 8	36·95	94·30	1314·7	Mean	280	
4		,, ,,		,,	,, ,,	7 6	36·95	93·60	1330·9	1322·2	284	
5		,, ,,		,,	,, ,,	7 3	36·80	94·25	1315·9		288	
LIV. 6		,, ,,	Segment shell.	3·084	11 9	8 10	36·75	98·55	1223·6		292	
7		,, ,,		,,	,, ,,	8 8	36·75	97·80	1238·9	1237·2	294	
8		,, ,,		,,	,, ,,	9 0	36·70	97·75	1237·1	Mean	291	
9		,, ,,		,,	,, ,,	8 10	36·85	98·45	1225·6	1227·4	327	
10		,, ,,		,,	,, ,,	9 9	36·70	98·40	1226·6		300	
11		,, ,,		,,	,, ,,	9 4	36·30	98·70	1212·7		315	
LV. 12		,, ,,	Cylinder, back portion similar to a shot.	,,	24 2½	20 9	36·90	123·10	845·5		200	
13		,, ,,		,,	24 1	21 0	36·70	122·70	850·3	856·7	190	
14		,, ,,		,,	24 14	21 1	36·65	122·85	848·5	Mean	201	
15		,, ,,		,,	24 8	19 7	36·60	121·10	870·2	853·9	205	
16		,, ,,		,,	24 3½	19 2	36·85	121·80	861·5		205	
17		,, ,,		,,	24 5	18 4	36·75	122·95	847·3		201	
LVI. 18		,, ,,	Ditto, wt. = 3 shots.	,,	35 10	22 11	36·40	113·40†	726·0		170	† Screens 90 ft. apart.
19		,, ,,		,,	36 6	21 0	36·55	115·05	708·8		163	
20		,, ,,		,,	35 15½	23 0	36·50	—	—	721·5	206	
21		,, ,,		,,	35 10	22 0	36·70	114·10	721·2	720·0	209	
22		,, ,,		,,	35 10	21 4	36·75	114·20	720·1		211	
23		,, ,,		,,	35 15	19 6	36·60	113·85	723·8		208	
LVII. 24		,, ,,	Ditto, wt. = 4 shots.	,,	47 12	21 9	36·65	123·95	625·5		110·0	Carriage broke down. Gun mounted on old 9-pr. carriage.
25		,, ,,		,,	48 3½	27 6	33·20	123·20	605·8		115·0	
26		,, ,,		,,	48 4	Impeded.	33·50	121·75	618·0	614·8	107·0	
27		,, ,,		,,	47 8	27 8	33·25	121·25	622·3	613·9	115·0	
28		,, ,,		,,	47 8	26 0	33·30	122·75	609·6		113·0	Carriage broke down.

March 13, 1861.—Barometer (32°), 30·075. Thermometer, dry, 43°·0; wet, 37°·0. Elastic force of vapour, ·142. Humidity, ·51. Weight of cubic foot of air, 554·5 grs. To ascertain the initial velocity of a 9-lb. shot fired from the service field gun.

No. of Rounds.	Nature of Ordnance.	Charge.	Projectile. Nature.	Projectile. Diameter.	Projectile. Weight.	Recoil.	Reading of Needle. Disjunctor.	Reading of Needle. Projector.	Velocity. At 25 yds.	Velocity. Initial.	Range.	REMARKS.
		lbs. oz.			lbs. oz.		°	°		ft.	yds.	
LVIII. 1	9-pr. brass gun No. 4894, wieght 13 cwt. 2 qrs. Cal. 4″·18.	0 14	Round shot.	4·08	9 5	2 11	35·60	—	—		209·0	Gun laid p. b. Ht. of line of axis of gun, 3′ 11½″. Powder W. A. Lot 260. Screens 90 ft. apart.
2		,, ,,		4·08	9 6	2 10	36·00	92·50	1004·9	Mean	200·0	
3		,, ,,		4·08	9 5	2 9	36·20	93·30	991·0	1011·2	—	
4		,, ,,		4·08	9 5	2 9	36·30	90·70	1037·6		200·0	
LIX. 5		1 8		4·09	9 5	4 5	33·20	75·15	1320·6	Mean	275·0	
6		,, ,,		4·08	9 6	4 3	33·20	75·40	1313·2	1310·9	269	
7		,, ,,		4·08	9 5	4 5	33·40	75·90	1298·8		115	

March 14, 1861.—Barometer (32°), 30·340. Therm. (dry,) 50°·3; wet, 46°·4. Elastic force of vapour, ·261. Humidity, ·72. Weight of cubic foot of air, 550·6 grs. To compare the initial velocities of a projectile fired from a rifled, and of one of the same weight and form fired from a smooth-bored gun.

No. of Rounds.	Nature of Ordnance.	Charge.	Projectile. Nature.	Projectile. Diameter.	Projectile. Weight.	Recoil.	Reading of Needle. Disjunctor.	Reading of Needle. Projector.	Velocity. At 30 yds.	Velocity. Initial.	Range.	Remarks.
		lbs. oz.			lbs. oz.		°	°	ft.	ft.	yds.	
LX. 1	32-pr. gun, No. 6,966. Weight, 58 cwt. 3 qrs. Calibre, 6·37.	5 8	Plugged shells for 32-pr. shunt gun. The first 4 were ribbed; the others round.	—	54 0	—	34·50	—	—	1224·5 Mean 1215·7	166·9	* Screens placed 30 yards apart. Height of axis of gun, 4 ft. Powder, A 4 W. A. 22/2/61. Lot 288.
2		,, ,,		—	,, ,,	8 1	34·55	80·90	1207·8*		190·0	
3		,, ,,		—	,, ,,	7 10	39·05	85·60	1222·1*		—	
4		,, ,,		—	,, ,,	8 0	39·40	101·75	1217·1		—	
LXI. 5	32-pr. rifled shunt gun, No. 6,341. Weight, 58 cwt. 3 qrs. Calibre,	,, ,,		—	,, ,,	—	34·70	85·15	1110·7*	1135·3 Mean 1122·1	—	
6		,, ,,		—	,, ,,	7 4	32·39	99·25	1117·3		249·0	
7		,, ,,		—	,, ,,	3 4	30·70	96·05	1138·3		266·6	
LXII. 8		,, ,,		—	,, ,,	3 1	31·50	96·10	1156·4	1201·7 Mean 1187·4	203·0	
9		,, ,,		—	,, ,,	3 4	31·55	93·75	1199·6		248·6	
10		,, ,,		—	,, ,,	3 0	31·60	94·60	1183·7		—	
11		,, ,,		—	,, ,,	2 10	31·75	—	—		357·6	
12		,, ,,		—	,, ,,	2 11	31·85	—	—		288·5	
13		,, ,,		—	,, ,,	3 5	32·00	94·60	1192·3		283·6	
14		,, ,,		—	,, ,,	3 4	32·10	95·25	1180·2		338·6	
15		,, ,,		—	,, ,,	3 5	32·00	93·55	1212·3		235·0	

March 15, 1861.—Barometer (32°), 30·245. Therm. dry, 53°·0; wet, 48°·0. Elastic force of vapour, ·269. Humidity, ·67. Weight of cubic foot of air, 545·9 grs. To compare the initial velocities or projectiles fired from a 32-pr. rifled shunt gun with charges made up in cartridges of various lengths.

No. of Rounds.	Nature of Ordnance.	Charge.	Projectile. Nature.	Projectile. Diameter.	Projectile. Weight.	Recoil.	Reading of Needle. Disjunctor.	Reading of Needle. Projector.	Velocity. At 30 yds.	Velocity. Initial.	Range.	Remarks.
		lbs. oz.			lbs. oz.		°	°	ft.	ft.	yds.	
LXIII. 1	32-pr. rifled shunt gun. No. 6,341.	5 8*	Plugged shells.	—	54 0	2 3½	32·00	100·60	1088·3	1061·7 Mean 1054·6	296·0	* Cartridge made up 12 ins. long. † Do. 9 do. ‡ Do. 8 do. § Do. 7½ do. ‖ Do. 6 do. Height of axis of gun, 4 ft. Powder A 4, W. A. 22/2/61. Lot 288.
2		,, ,,*		—	,, ,,	2 1½	30·70	102·80	1032·4		277·0	
3		,, ,,*		—	,, ,,	2 3½	30·75	—	—		312·3	
4		,, ,,*		—	,, ,,	2 3	30·75	102·15	1042·0		254·6	
LXIV. 5		,, ,,†		—	,, ,,	2 6	30·85	100·50	1067·1	1084·2 Mean 1076·8	276·3	
6		,, ,,†		—	,, ,,	2 7	30·85	99·95	1075·7		325·2	
7		,, ,,†		—	,, ,,	2 6	30·90	99·20	1087·6		296·0	
LXV. 8		,, ,,‡		—	,, ,,	3 0	30·70	98·30	1102·2	1109·8	331·3	
LXVI. 9		,, ,,§		—	,, ,,	3 0	30·85	97·55	1114·5	1122·3	329·0	
LXVII. 10		,, ,,‖		—	,, ,,	3 6	30·80	93·40	1187·4	1196·4 Mean 1187·9	311·6	
11		,, ,,‖		—	,, ,,	3 6	30·75	93·35	1188·3		305·5	

Same date and circumstances as above. Experiments to ascertain the initial velocity of a 12-pr. Armstrong shell fired from a 12-pr. of 6 cwt.

No. of Rounds.	Nature of Ordnance.	Charge.	Projectile. Nature.	Projectile. Diameter.	Projectile. Weight.	Recoil.	Reading of Needle. Disjunctor.	Reading of Needle. Projector.	Velocity. At 30 yds.	Velocity. Initial.	Range.	Remarks.
		lbs. oz.			lbs. oz.		°	°	ft.	ft.	yds.	
LXVIII. 1	—	1 6	—	3·074	11 9	6 7	30·95	—	—	1111·8 Mean 1103·4	313·0	Gun laid p. b. H. L. of axis 4 ft. Powder A 4, Hall and Sons, 11/7/60. Lot 2. * False connexion.
2	—	,, ,,	—	,,	,, ,,	7 0	30·85	97·60	1113·71		293·0	
3	—	,, ,,	—	,,	,, ,,	6 3	30·75	—*	—		330·0	
4	—	,, ,,	—	,,	,, ,,	6 6	30·70	—	—		366·6	
5	—	,, ,,	—	,,	,, ,,	6 9	30·70	—	—		335·6	
6	—	,, ,,	—	,,	,, ,,	7 0	30·75	97·89	1109·6		359·3	
7	—	,, ,,	—	,,	,, ,,	7 9	30·85	98·85	1093·2		329·6	
8	—	,, ,,	—	,,	,, ,,	7 8	30·95	98·60	1097·3		299·1	

Same date and circumstances as before. Experiments to ascertain the effect of diminishing the lead on the base of the 12-pr. Armstrong projectile.

No. of Rounds.	Nature of Ordnance.	Charge.	Projectile. Nature.	Projectile. Diameter.	Projectile. Weight.	Recoil.	Reading of Needle. Disjunctor.	Reading of Needle. Projector.	Velocity. At 30 yds.	Velocity. Initial.	Range.	REMARKS.
		lbs. oz.			lbs. oz.		°	°	ft.	ft.	yds.	
LXIX. 1	12-pr. Armstrong. No. 1,050.	1 8	—	3·074	11 9	6 9	30·75	92·45	1205·3	1248·2 Mean 1238·3	289·3	Segment shells fired under normal circumstances.
2		,, ,,	—	,,	,, ,,	8 6	30·70	90·45	1244·4		265·3	
3		,, ,,	—	,,	,, ,,	7 6	30·75	90·60	1241·4		312·3	
4		,, ,,	—	,,	,, ,,	8 5	30·60	90·75	1229·0		315·0	
LXX. 5		,, ,,	—	3·01	,, ,,	8 3	30·75	93·70	1183·7	1209·7 Mean 1200·2	269·0	Same shell turned down to the diameter 3·01 ins., with the exception of a ring about 25 ins. at base.
6		,, ,,	—	,,	,, ,,	8 0	30·89	91·95	1216·8		—	
LXXI. 7		,, ,,	—	,,	,, ,,	—	30·95	94·90	1161·9	1172·8 Mean 1163·7	—	Same shell turned down throughout to the diameter 3·01 ins.
8		,, ,,	—	,,	,, ,,	—	30·80	94·70	1165·5		293·6	
LXXII. 9		,, ,,	—	,,	,, ,,	—	30·90	99·75	1080·4	1097·9 Mean 1089·6	245·3	
10		,, ,,	—	,,	,, ,,	—	30·95	98·60	1098·8		266·0	
												Powder, A 4, Hall and Sons, 11/7/60. Lot 2. Last 2 rounds a different powder, A 4, W. A. 5/9/60. Lot 288 were used.

No. 12.

October 17, 1860.—Barometer (32°), 30·090. Therm. dry, 51°·5; wet, 47°·4. Elastic force of vapour, ·273. Humidity, ·72. Weight of cubic foot of air, 544·7 grs. To ascertain the difference, if any, in initial velocity or regularity between two Armstrong guns, one of which had been exposed for several weeks without protection to the weather.

		lbs. oz.			lbs. oz.		°	°	ft.	ft.	yds.	
1	12-pr. Armstrong, No. 8. Weight, 8 cwt. 2 qrs. 13 lbs.	1 8	Segment shell weighted.	3·085	11 9	—	41·40	109·55	1115·2*	1136·3 Mean 1127·6	255·0	This gun had been exposed (without being touched) to the weather for several weeks. It appeared to have been well greased. It was fired without being cleaned. There was no difficulty in working it. Lubricating wads were employed. Powder, A4. Gun mounted on field carriage. * Not included in the mean.
2		,, ,,		,,	,, ,,	—	41·40	108·40	1136·0		265·0	
3		,, ,,		,,	,, ,,	—	41·45	108·40	1136·0		265·0	
4		,, ,,		,,	,, ,,	—	41·60	108·30	1137·9		264·0	
5		,, ,,		,,	,, ,,	—	41·55	108·80	1128·7		262·0	
6		,, ,,		,,	,, ,,	—	41·50	108·75	1129·6		260·0	
7		,, ,,		,,	,, ,,	—	41·55	109·00	1125·2		256·0	
8		,, ,,		,,	,, ,,	—	41·50	—	—		260·0	
9		,, ,,		,,	,, ,,	—	41·60	109·20	1122·7		257·0	
10		,, ,,		,,	,, ,,	—	41·45	109·10	1124·5		262·0	
11		,, ,,		,,	,, ,,	—	41·50	109·15	1123·6		268·0	
12		,, ,,		,,	,, ,,	—	41·70	109·10	1124·5		269·0	
13		,, ,,		,,	,, ,,	—	41·50	109·25	1121·8		268·0	
14		,, ,,		,,	,, ,,	—	—	109·15	1123·6		260·0	
15		,, ,,		,,	,, ,,	—	41·65	109·10	1124·5		259·0	
16	12-pr. Armstrong, No. 224. Weight, 8 cwt. 2 qrs. 19 lbs.	1 8	Segment shell weighted.	3·085	11 9	—	41·65	108·95	1128·6*	1150·6 Mean. 1141·8	310·0	This gun was new and very clean. Lubricating wads used. * Not included in the mean.
17		,, ,,		,,	,, ,,	—	41·50	108·15	1143·4		312·0	
18		,, ,,		,,	,, ,,	—	41·60	108·05	1145·3		311·0	
19		,, ,,		,,	,, ,,	—	41·60	107·95	1147·1		300·0	
20		,, ,,		,,	,, ,,	—	41·50	107·80	1150·0		269·0	
21		,, ,,		,,	,, ,,	—	41·75	108·40	1136·9		282·0	
22		,, ,,		,,	,, ,,	—	41·50	108·25	1139·7		310·0	
23		,, ,,		,,	,, ,,	—	41·50	108·35	1137·9		287·0	
24		,, ,,		,,	,, ,,	—	41·50	108·65	1132·3		286·0	
25		,, ,,		,,	,, ,,	—	41·60	108·45	1136·0		310·0	
26		,, ,,		,,	,, ,,	—	41·45	108·05	1145·3		296·0	
27		,, ,,		,,	,, ,,	—	41·50	107·40	1155·6		300·0	
28		,, ,,		,,	,, ,,	—	41·45	—	—		320·0	
29		,, ,,		,,	,, ,,	—	41·50	108·05	1145·3		282·0	
30		,, ,,		,,	,, ,,	—	41·50	108·80	1129·6		268·0	

October 20, 1860.—Barometer (32°), 29·930. Therm. dry, 52°·5; wet, 48°·3. Elastic force of vapour, ·283. Humidity, ·71. Weight of a cubic foot of air, 540·7 grs. To ascertain the initial velocity of 25-pr. projectiles fired from the long 25-pr. with various charges.

No. of Rounds.	Nature of Ordnance.	Charge.	Projectile. Nature.	Projectile. Diameter.	Projectile. Weight.	Recoil.	Reading of Needle. Disjunctor.	Reading of Needle. Projector.	Velocity. At 30 yds.	Velocity. Initial.	Range.	Remarks.
		lbs. oz.			lbs. oz.		°	°	ft.	ft.	yds.	
1	25-pr. Armstrong, R.G.C., No. 384. Weight, 18 cwt. 1 qr. 22 lbs. Calibre, 3·75.	2 8	Segment shell weighted to 25 lbs. with buck shot.	3·830	25 0	—	41·65	119·70	953·1		—	Rounds 1 to 6 no lubricating wads were used. Lubricating wads were used in the rest of the practice. Height of axis of gun, 4 ft. 3½ ins. Gun laid horizontal. Powder, A 4.
2		,, ,,		,,	,, ,,	—	36·65	—	—		—	
3		,, ,,		,,	,, ,,	—	36·70	—	—	968·8 Mean 963·8	—	
4		,, ,,		,,	,, ,,	—	32·45	109·95	963·5		—	
5		,, ,,		,,	,, ,,	—	35·70	112·95	968·5		—	
6		,, ,,		,,	,, ,,	—	35·70	112·85	969·9		—	
7		,, ,,		,,	,, ,,	—	35·65	111·65	986·9		—	
8		,, ,,		,,	,, ,,	—	35·60	110·25	1007·3		—	
9		,, ,,		,,	,, ,,	—	35·60	109·25	1016·5	1019·8 Mean 1014·4	—	
10		,, ,,		,,	,, ,,	—	35·20	109·50	1012·8		—	
11		,, ,,		,,	,, ,,	—	35·30	108·95	1021·0		—	
12		,, ,,		,,	,, ,,	—	40·75	111·20	1076·4		—	
13		2 13		,,	,, ,,	—	41·00	110·60	1086·7		—	
14		,, ,,		,,	,, ,,	—	40·90	110·70	1085·0		—	
15		,, ,,		,,	,, ,,	—	41·00	110·79	1084·1		—	
16		,, ,,		,,	,, ,,	—	40·85	111·00	1079·8		—	
17		,, ,,		,,	,, ,,	—	40·95	111·00	1079·8	1089·3 Mean 1083·3	—	
18		,, ,,		,,	,, ,,	—	40·95	110·70	1085·0		—	
19		,, ,,		,,	,, ,,	—	41·00	110·65	1085·8		—	
20		,, ,,		,,	,, ,,	—	40·90	110·55	1087·5		—	
21		,, ,,		,,	,, ,,	—	43.75	113·55	1084·3		—	
22		,, ,,		,,	,, ,,	—	43·80	111·70	1081·7		—	
23		3 2		,,	,, ,,	—	44·00	110·50	1121·4		—	
24		,, ,,		,,	,, ,,	—	—	—	—		—	
25		,, ,,		,,	,, ,,	—	—	—	—		—	
26		,, ,,		,,	,, ,,	—	45·50	112·80	1129·2		—	
27		,, ,,		,,	,, ,,	—	45·65	112·65	1132·1	1142·5 Mean 1136·1	—	
28		,, ,,		,,	,, ,,	—	45·55	111·60	1152·3		—	
29		,, ,,		,,	,, ,,	—	45·80	112·35	1137·8		—	
30		,, ,,		,,	,, ,,	—	45·85	113·10	1123·5		—	
31		,, ,,		,,	,, ,,	—	45·25	111·65	1146·1		—	
32		,, ,,		,,	,, ,,	—	45·50	112·75	1125·0		—	
33		,, ,,		,,	,, ,,	—	45·45	111·80	1143·2		—	

October 20, 1860.—Barometer (32°), 29·930. Therm. dry, 52°·5; wet, 48°·3. Elastic force of vapour, ·283. Humidity ·71. Weight of cubic foot of air, 540·7 grs. To ascertain the initial velocity of 25-pr. projectiles fired from a short 25-pr. with a charge of 2 lbs. 6 oz.

No. of Rounds.	Nature of Ordnance.	Charge.	Projectile. Nature.	Projectile. Diameter.	Projectile. Weight.	Recoil.	Reading of Needle. Disjunctor.	Reading of Needle. Projector.	Velocity. At 30 yds.	Velocity. Initial.	Range.	Remarks.
		lbs. oz.			lbs. oz.		°	°	ft.	ft.	yds.	
1	25-pr. Armstrong, R.G.C. No. 403. Weight, 12 cwt. 1 qr. 19 lbs.	2 6	—	3·830	25 0	—	45·20	131·20	832·4		—	Lubricating wads employed. Same powder used as with the long 25-pr. Height of axis, 4 ft.
2		,, ,,	—	,,	,, ,,	—	45·40	127·55	883·8		—	
3		,, ,,	—	,,	,, ,,	—	45·20	127·80	880·2		—	
4		,, ,,	—	,,	,, ,,	—	45·55	127·70	881·7	878·9 Mean. 874·5	—	
5		,, ,,	—	,,	,, ,,	—	45·60	128·20	874·5		—	
6		,, ,,	—	,,	,, ,,	—	45·20	127·55	883·8		—	
7		,, ,,	—	,,	,, ,,	—	45·45	127·45	885·3		—	

No. 14.

RESULT of EXPERIMENTS made to ascertain the ANGLE of DEPARTURE and the TRAJECTORIES of the 12-PR. ARMSTRONG PROJECTILES when laid P.B., and at an apparent elevation of 30′.

Charge.	Weight of Projectile.	Reading of Needle.		Velocities.		Angle of Departure.	Ordinates at																		Range in Yards.	REMARKS.
							90 ft.		150 ft.		300 ft.		450 ft.		600 ft.		750 ft.		900 ft.		1,200 ft.		1,350 ft.			
		unctor.	Projectile.	At 30 Yards.	Initial.		Observed.	Computed.	Observed.	Computed.	Observed.	Computed.	Observed.	Computed.	Observed.	Computed.	Observed.	Computed.	Observed.	Computed.	Observed.	Computed.	Observed.	Computed.		
September 10, 1860.—Bar. (32°), 30·210. Therm., dry, 55°·2; wet, 53°·0. Wind No. 2. Elasticity, ·373. Humidity, ·86. Weight of cubic foot of air, 542·2 grs.																										
lbs. oz.	lbs. oz.	°	°			° ′ ″	ft.	ft.	ft.	ft.	ft.	ft.	ft.	ft.	ft.	ft.	ft.	ft.	ft.	ft.	ft.	ft.	ft.	ft.	yds.	
1 8	11 9	42·60	107·60	1176·1	1185·3	0. 23. 44	4·817	4·775	5·025	5·019	5·133	5·24	4·692	4·889	4·058	3·948	—	—	—	—	—	—	—	—	283	Laid hori-
,, ,,	,, ,,	42·70	108·05	1167·2	1176·4	0. 28. 28	4·9	4·9	5·233	5·227	5·683	5·639	5·483	3·525	4·908	4·821	3·808	4·155	—	—	—	—	—	—	307	zontal with
,, ,,	,, ,,	42·85	107·45	1179·0	1188·2	0. 28. 3	4·892	4·793	5·117	5·214	5·45	5·646	5·242	5·532	4·575	4·824	3·683	3·534	—	—	—	—	—	—	312	spirit level.
,, ,,	,, ,,	42·75	,,	1173·2	1182·3	0. 23. 57	4·783	4·78	5·025	5·043	5·3	5·277	4·967	4·961	4·35	4·063	2·817	2·569	—	—	—	—	—	—	306	
,, ,,	,, ,,	42·80	,,	1173·2	1182·3	0. 26. 23	4·883	4·848	5·117	5·117	5·425	5·49	5·25	5·28	5·125	4·489	4·417	3·955	—	—	—	—	—	—	322	
,, ,,	,, ,,	42·85	107·50	1178·0	1187·2	0. 25. 50	4·833	4·833	5·017	5·118	5·508	5·451	5·158	5·235	4·833	4·431	—	—	—	—	—	—	—	—	316	Gun, No. 224.
,, ,,	,, ,,	42·90	108·15	1165·3	1174·4	0. 26. 52	4·858	4·858	5·058	5·158	5·633	5·524	5·45	5·324	4·275	4·54	—	—	—	—	—	—	—	—	290	
September 15, 1860.—Bar. (32°), 29·690. Therm., dry, 57°·0; wet, 53°·1. Calm. Elastic force of vapour, ·350. Humidity, ·75. Weight of a cubic foot of air, 531·4 grs.																										
lbs. oz.	lbs. oz.	°	°			° ′ ″	ft.	ft.	ft.	ft.	ft.	ft.	ft.	ft.	ft.	ft.	ft.	ft.	ft.	ft.	ft.	ft.	ft.	ft.	yds.	
1 8	11 9	42·75	106·25	1201·6	1211·1	0. 25. 42	4·833	4·83	—	5·127	5·743	5·503	5·575	5·357	4·933	4·67	3·717	4·278	—	—	—	—	—	—	319	Laid hori-
,, ,,	,, ,,	42·75	107·40	1178·6	1187·8	0. 25. 3	4·812	4·81	—	5·083	5·608	5·393	5·417	5·122	4·517	4·296	3·25	2·873	—	—	—	—	—	—	310	zontal with
,, ,,	,, ,,	42·80	106·75	1191·5	1200·9	0. 23. 32	4·775	4·775	—	4·984	5·292	5·12	4·975	4·632	3·9	3·498	2·542	—	—	—	—	—	—	—	305	spirit level.
,, ,,	,, ,,	42·60	106·55	1195·6	1205·0	0. 23. 30	4·775	4·76	—	5·023	5·267	5·277	4·917	4·992	4·433	4·148	3·208	2·73	—	—	—	—	—	—	303	
,, ,,	,, ,,	42·70	107·70	1172·7	1181·9	0. 47. 0	5·492	5·387	—	6·039	7·308	7·288	8·084	7·977	7·958	8·084	7·5	7·593	5·75	6·398	—	—	—	—	410	30′ elevation.
September 19, 1860.—Bar. (32°), 29·685. Therm., dry, 59°·0; wet, 55°·9. Wind No. 2. Elastic force of vapour, ·409. Humidity, ·82. Weight of a cubic foot of air, 528·6 grs.																										
lbs. oz.	lbs. oz.	°	°			° ′ ″	ft.	ft.	ft.	ft.	ft.	ft.	ft.	ft.	ft.	ft.	ft.	ft.	ft.	ft.	ft.	ft.	ft.	ft.	yds.	
1 8	11 9	41·75	106·55	1181·0	1190·2	0. 48. 6	5·451	5·416	—	6·09	7·25	7·399	8·042	8·154	8·151	8·377	7·651	7·929	6·517	6·825	4·792	—	1·583	—	464	30′ elevation.
,, ,,	,, ,,	41·75	106·40	1184·0	1193·3	0. 49. 6	5·417	5·443	—	6·136	7·567	7·491	8·583	8·296	8·808	8·533	8·533	8·183	7·508	7·139	—	—	0·000	—	452	
,, ,,	,, ,,	—	106·10	1190·0	1199·4	0. 49. 6	5·417	5·443	—	6·138	7·567	7·502	8·583	8·321	8·767	8·576	8·422	8·251	7·492	7·24	—	—	0·200	—	448	
,, ,,	,, ,,	42·75	107·45	1163·5	1172·6	0. 48. 18	5·41	5·42	—	6·086	7·3	7·373	8·208	8·086	8·125	8·206	7·9	7·718	6·842	6·53	—	—	—	—	—	

APPENDIX I.

Experiments made to determine the time of a small oscillation of the pendulum belonging to No. 24, Major Navez's Ballistic Apparatus.

N.B. The pendulum was removed from the instrument and swung in the needles. Care was taken that the vernier occupied its proper position with regard to the bob of the pendulum.

24th July 1860.

1st series	200	vibrations in	66·6	seconds.
,,	700	,,	232·5	,,
,,	200	,,	66·7	,,
,,	200	,,	66·5	,,
,,	200	,,	66·6	,,
,,	200	,,	66·6	,,
,,	500	,,	166·3	,,
,,	200	,,	66·5	,,
,,	300	,,	99·9	,,
,,	500	,,	166·6	,,
,,	500	,,	166·2	,,
,,	500	,,	166·5	,,
,,	500	,,	166·6	,,
,,	200	,,	66·4	,,
,,	200	,,	66·6	,,
,,	200	,,	66·4	,,
,,	200	,,	66·5	,,
,,	200	,,	66·7	,,
	5,700		1896·7	

25th July 1860.

2nd series	400	vibrations in	132·8	seconds.
,,	400	,,	132·9	,,
,,	400	,,	132·8	,,
,,	200	,,	66·5	,,
,,	500	,,	166·2	,,
,,	400	,,	133·0	,,
,,	200	,,	66·4	,,
,,	400	,,	132·8	,,
,,	500	,,	166·3	,,
	3,400		1129·7	

25th July 1860.

3rd series	400	vibrations in	133·1	seconds.
,,	200	,,	66·5	,,
,,	200	,,	66·6	,,
,,	400	,,	133·0	,,
,,	100	,,	33·2	,,
,,	400	,,	132·9	,,
,,	400	,,	133·1	,,
,,	400	,,	133·1	,,
,,	400	,,	132·9	,,
,,	100	,,	33·2	,,
,,	400	,,	133·1	,,
	3,400		1130·7	

Hence, taking the sum in each of the above series, we have—

5,700	vibrations in	1896·7	seconds.
3,400	,,	1129·7	,,
3,400	,,	1130·7	,,
12,500		4157·1	
	Chronometer fast	6·9	
12,500		4150·2	

Or the time of one small oscillation $=0{\cdot}3320$ seconds.

APPENDIX II.

Experiments made to determine the time of a small oscillation of the pendulum of instrument No. 32.

The same precautions were adopted as in the case of instrument No. 24.

5th March 1861.

100	vibrations in	33·3	seconds.
100	,,	33·3	,,
150	,,	49·9	,,
150	,,	50·1	,,
100	,,	33·4	,,
300	,,	99·8	,,
200	,,	66·9	,,
200	,,	66·8	,,
200	,,	67·1	,,
200	,,	66·9	,,
200	,,	66·9	,,
200	,,	66·9	,,
200	,,	66·8	,,
200	,,	66·8	,,
200	,,	66·9	,,
200	,,	67·0	,,
200	,,	67·0	,,
200	,,	67·0	,,
200	,,	67·0	,,
200	,,	66·9	,,
400	,,	133·6	,,
400	,,	133·4	,,
400	,,	133·5	,,
4,900		1636·9	
	Chronometer fast	1·2	
		1635·7	

Or one small oscillation in 0·3337 seconds.

APPENDIX III.

Table showing the Times corresponding to the Arcs for Instrument No. 24, the time of a small Oscillation being = 0·3320 seconds.

Arc.	Total Duration.	Partial Duration.	Arc.	Total Duration.	Partial Duration.	Arc.	Total Duration.	Partial Duration.	Arc.	Total Duration.	Partial Duration.
°			°			°			°		
30	·111823	·001935	56	·156519	·001571	82	·196291	·001524	108	·237702	·001719
31	·113758	·001910	57	·158090	·001564	83	·197815	·001526	109	·239421	·001735
32	·115668	·001885	58	·159654	·001559	84	·199341	·001529	110	·241156	·001750
33	·117553	·001863	59	·161213	·001554	85	·200870	·001532	111	·242906	·001766
34	·119416	·001842	60	·162767	·001548	86	·202402	·001536	112	·244672	·001784
35	·121257	·001821	61	·164315	·001544	87	·203938	·001540	113	·246457	·001802
36	·123078	·001802	62	·165859	·001540	88	·205478	·001544	114	·248259	·001821
37	·124880	·001784	63	·167399	·001536	89	·207022	·001548	115	·250079	·001842
38	·126664	·001766	64	·168935	·001532	90	·208570	·001554	116	·251921	·001863
39	·128431	·001750	65	·170467	·001529	91	·210124	·001559	117	·253784	·001885
40	·130181	·001735	66	·171966	·001526	92	·211683	·001564	118	·255669	·001910
41	·131916	·001719	67	·173522	·001524	93	·213247	·001571	119	·257579	·001935
42	·133635	·001706	68	·175046	·001522	94	·214818	·001578	120	·259514	·001962
43	·135341	·001693	69	·176568	·001520	95	·216396	·001584	121	·261476	·001990
44	·137034	·001680	70	·178088	·001518	96	·217980	·001591	122	·263466	·002021
45	·138713	·011668	71	·179606	·001517	97	·219571	·001600	123	·265486	·002052
46	·140381	·001656	72	·181123	·001516	98	·221171	·001607	124	·267539	·002087
47	·142037	·001645	73	·182689	·001515	99	·222778	·001616	125	·269626	·002124
48	·143682	·001635	74	·184153	·001515	100	·224394	·001625	126	·271756	·002163
49	·145318	·001625	75	·185668	·001515	101	·226019	·001635	127	·273912	·002204
50	·146943	·001616	76	·187183	·001515	102	·227654	·001645	128	·276117	·002250
51	·148559	·001607	77	·188698	·001516	103	·229300	·001656	129	·278367	·002299
52	·150166	·001600	78	·190214	·001517	104	·230956	·001668	130	·280665	·002351
53	·151766	·001591	79	·191731	·001518	105	·232623	·001680	131	·283017	·002409
54	·153357	·001584	80	·193249	·001520	106	·234303	·001693	132	·285426	002472
55	·154952	·001578	81	·194769	·001522	107	·235996	·001706	133	....	....

APPENDIX IV.

TABLE showing the TIMES corresponding to the ARCS for INSTRUMENT No. 32, the time of a small Oscillation being = 0·3337 seconds.

Arc.	Total Duration.	Partial Duration.	Arc.	Total Duration.	Partial Duration.	Arc.	Total Duration.	Partial Duration.	Arc.	Total Duration.	Partial Duration.
°			°			°			°		
30	·112397	·001945	56	·157322	·001578	82	·197298	·001531	108	·238922	·001728
31	·114342	·001919	57	·158901	·001572	83	·198830	·001533	109	·240650	·001743
32	·116261	·001895	58	·160473	·001566	84	·200364	·001536	110	·242393	·001759
33	·118156	·001872	59	·162040	·001561	85	·201900	·001540	111	·244153	·001775
34	·120028	·001851	60	·163602	·001556	86	·203441	·001543	112	·245928	·001793
35	·121879	·001830	61	·165158	·001551	87	·204985	·001547	113	·247721	·001811
36	·123710	·001811	62	·166710	·001547	88	·206537	·001551	114	·249533	·001830
37	·125521	·001793	63	·168258	·001543	89	·208084	·001556	115	·251363	·001851
38	·127314	·001775	64	·169801	·001540	90	·209641	·001561	116	·253214	·001872
39	·129090	·001759	65	·171342	·001536	91	·211202	·001566	117	·255086	·001895
40	·130849	·001743	66	·172870	·001533	92	·212769	·001572	118	·256981	·001919
41	·132592	·001728	67	·174413	·001531	93	·214342	·001578	119	·258901	·001945
42	·134321	·001714	68	·175944	·001529	94	·215920	·001585	120	·260846	·001972
43	·136035	·001701	69	·177474	·001527	95	·217505	·001592	121	·262818	·001999
44	·137737	·001688	70	·179002	·001525	96	·219098	·001599	122	·264818	·002030
45	·139425	·001676	71	·180527	·001524	97	·220698	·001607	123	·266849	·002062
46	·141102	·001664	72	·182052	·001523	98	·222306	·001615	124	·268912	·002097
47	·142766	·001653	73	·183576	·001522	99	·223921	·001624	125	·271009	·002134
48	·144420	·001643	74	·185098	·001522	100	·225546	·001633	126	·273144	·002173
49	·146063	·001633	75	·186621	·001522	101	·227179	·001643	127	·275318	·002215
50	·147697	·001624	76	·188144	·001522	102	·228823	·001653	128	·277534	·002261
51	·149321	·001615	77	·189667	·001523	103	·230476	001664	129	·279795	·002310
52	·150937	·001607	78	·191190	·001524	104	·232141	·001676	130	·282106	·002363
53	·152544	·001599	79	·192715	·001525	105	·233817	·001688	131	·284469	·002421
54	·154144	·001592	80	·194241	·001527	106	·235506	·001701	132	·286891	·002484
55	·155737	·001585	81	·195768	·001529	107	·237207	·001714	133	....	....

N.B.—The foregoing interesting Report was furnished to the members of the Royal Artillery Institution by the Right Honourable the Secretary of State for War.

DESCRIPTION

OF

NAVEZ'S ELECTRO-BALLISTIC APPARATUS,*

FOR DETERMINING THE VELOCITY OF PROJECTILES.

BY LIEUTENANT W. H. NOBLE, R.A.

HAVING been requested by the R.A. Institution to furnish them with a full description of this apparatus, as a supplement to the valuable report by Captain Noble, late R.A., printed in the R.A. Institution "Proceedings," Vol. III. p. 117, I beg to submit the following pages in hopes that they may prove acceptable. Captain Noble has given a short account of this instrument which, although quite sufficient for a report to those who were intimately acquainted with the apparatus, was not intended for the guidance of such as have never had an opportunity of witnessing experiments with the electro-ballistic machine.

In order thoroughly to understand the nature and working of the instrument, the reader must be somewhat acquainted with the elements of electricity, galvanism, and magnetism, which can be studied in any book on the subject.

I would suggest attention to the following points :—

(1) Nature of an electric current.

(2) Conductors and non-conductors of electricity.

(3) The voltaic battery. Elements of Bunsen's, and Groves's batteries.

(4) Magnetization of soft iron by the electric current. Electro magnets.

(5) The necessity of complete insulation in the wires conducting electric currents.

(6) Velocity of the propagation of electricity.

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1. Major Navez's electro-ballistic apparatus consists of three distinct and separate parts :—

The Pendulum Proper.
The Conjunctor.
The Disjunctor.

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* Major Navez, Belgian Artillery, has published a book of instructions on this subject, which has been very clearly translated by Lieut.-Col. C. W. Younghusband, R.A.

The diagrams and woodcuts belonging to this translation have been placed at the disposal of the R.A. Institution by the War Office.

The Pendulum Proper (Plate I).

2. Consists of a strong brass plate *a*, bearing a limb *o* graduated on silver from 0° to 150°. An opening in the centre of this plate admits of the adjustment of the axis of suspension *d* of a pendulum *b*, formed of a steel rod *b* with collar and brass bob *c*, into which bob a small plug of soft iron is inserted. The axis of the pendulum is perpendicular to the face of the plate. This pendulum consists of two parts, the steel rod bearing the bob, and an index needle *l*, fixed through a collar to an iron washer or circular disc *j*. A forked spring *k*, presses the collar of the needle against the collar of the pendulum rod. The result of this arrangement is that when the pendulum rod is put in motion it carries the needle with it, and the whole oscillating system consists then of the pendulum rod with its bob and collar; the needle with its bob, collar, and iron washer; and the axis of suspension or prolongation of the pendulum collar.

An opening towards the side of the brass plate admits the adjustment of a straight electro-magnet *r*. At the centre opening, immediately behind the iron washer, a strong horseshoe electro-magnet *u* is fixed, so that when the oscillating system is set in motion the poles of the magnet are extremely close to the posterior face of the iron washer *j*. A base of wood *X* supports the whole apparatus; this base is provided with levelling screws *YY*, pressure screws *WW*, to establish communication with the electro-magnets; and a spirit-level *Z* perpendicular to the face of the instrument.

The vernier of the needle is graduated to read the $\frac{1}{20}$ of 1°, or 3 minutes.

The Conjunctor (Plate II).

3. Consists of two upright brass rods *bb*, upon which a straight electro-magnet *a* is made to slide. Each of these rods is furnished at its lower extremity with a pressure screw *d*, to establish communication with the electro-magnet; the electric current arrives by one rod, magnetizes the electro-magnet, and returns by the other rod.

Under the electro-magnet is a small iron cup *f*, connected with a pressure screw by a strip of copper *k*. In this cup a little mercury is placed. The height of this mercury can be regulated by a screw *g*, with a divided head *o*. To another pressure screw a steel blade *l* is attached, carrying a pin which can be placed exactly over the orifice in the iron cup. The cup is surrounded with a movable brass cylinder *j*, which can be taken off to examine the mercury, &c. A leaden weight *r* with a soft iron head completes the conjunctor.

The Disjunctor (Plate III).

4. Two straight springs *aa* are mortised into two pressure screws. A small screw *b*, with platinum point, is inserted into the free extremity of each of these springs. Two other screws, with platinum points, are arranged in brass supports *c*, so that their points are presented to the points of the spring screws. The supports *c* are furnished with pressure screws.

Upon the middle of the base a brass cylinder *d* is fixed, containing a spiral spring *e*, and piston *f*; at one extremity of the piston is an ivory buffer *g*, at the other extremity a brass handle *h*. When the piston rod is drawn back it cocks on a trigger *i* placed behind in a direction perpendicular to the rod.

When the disjunctor is thus cocked the ivory buffer no longer presses against the two straight springs, and the two pair of screws with platinum points are allowed to come in contact with each other. Then, if one electric circuit includes the two pressure screws on the right, and another electric circuit the two pressure screws on the left, free communication will take place, as the little platinum pointed screws will be touching. But if the button on the trigger be pressed, the piston rod is allowed to fly back, and the ivory buffer strikes against *both* the springs, and by detaching the points of the little platinum pointed screws from each other, breaks both circuits *exactly at the same moment.*

Adjustment of the Apparatus.

5. The apparatus must be placed in a spot well sheltered from wind and dust, and at a sufficient distance from the gun to avoid the disturbing influences arising from the shock of the discharge. The pendulum and conjunctor are set upon a solid heavy table, perfectly insulated from the building in which it is erected. The disjunctor is set on a table placed beside the other.

6. It is important that the pendulum should be so adjusted, that the oscillating system, in vibrating from its initial position to that of equilibrium, should pass through an arc of 75°. This is performed by means of the two levelling screws on the left of the base, and the adjusting screw on the right.

The suspension of the pendulum is regulated, so that the washer is made to oscillate as near as possible to the poles of the large electro-magnet without touching them.

7. In the conjunctor care is taken that the mercury is quite pure, and the point of the pin free from oxidation.

In the disjunctor the platinum pointed screws are arranged, so that there is an interval between their respective points something greater than the thickness of a piece of writing paper.

Voltaic Batteries.

8. Two batteries must be employed, the elements may be either those of Bunsen or Grove.

The battery should be outside the room in which the instrument is, but should not be removed very far, in order that the current which magnetizes the large electro-magnet, may meet with as little resistance as possible.

Frame Targets.

9. The frame targets are made of well dried wood, and of just sufficient size to afford a good mark in firing, Fig. 1. The sides of the targets are

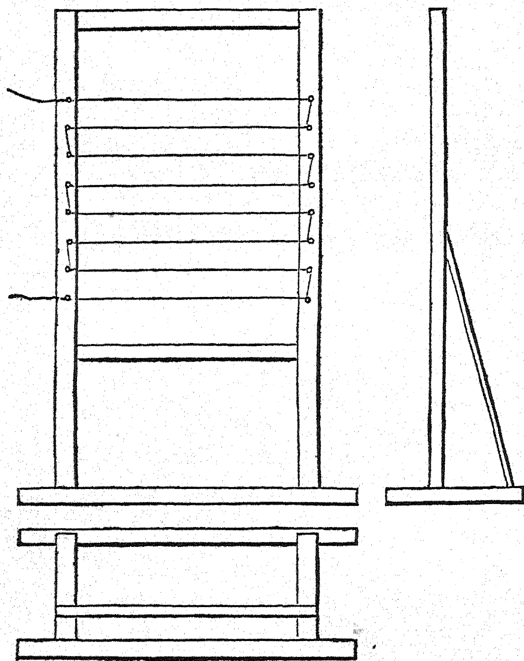


Fig. 1.

furnished with a range of pins, covered with gutta percha, and the wires are stretched by these pins across the target, two or three turns being taken round each pin. The distance between the wires is made equal to about half the diameter of the projectile used. When it is necessary to mend the wire, after a shot has passed through the target, it is done by simply twisting the two broken pieces together, Fig. 2. The copper wire employed in making Artillery experiments should not be more than 0·012 in. in diameter. The targets are generally made about 30 by 60 ins., a cross piece being placed about 20 ins. from the bottom, and so reducing the space through which the shot passes to 30 by 40 ins. When the first target is near the muzzle of the gun it is necessary to protect it from the blast of the discharge; for this purpose a screen (Fig. 3, p. 155), formed of strong plank, is interposed between the gun and the first target. A hole, about $1\frac{1}{2}$ calibres in diameter, is cut in the centre of this screen, to admit of the shot passing it.

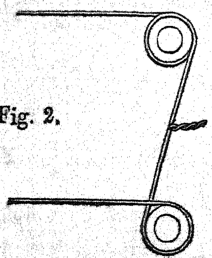


Fig. 2.

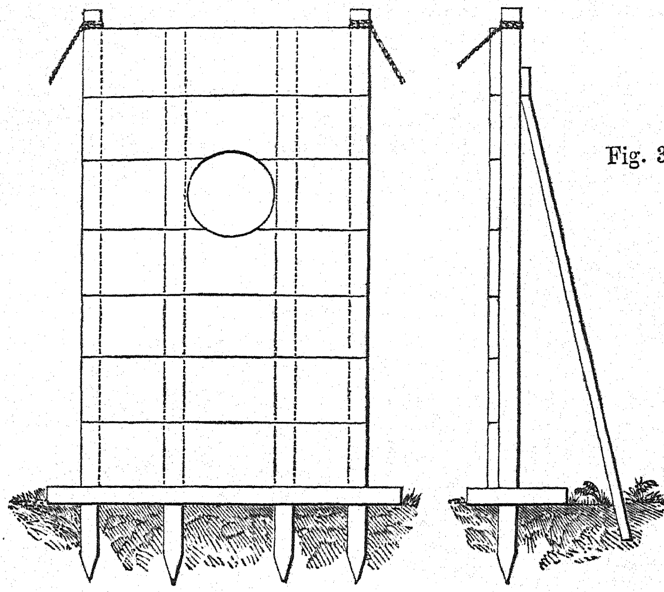
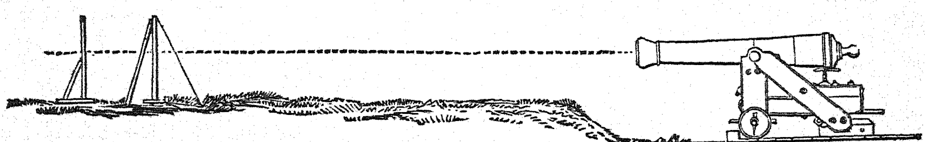


Fig. 3.



Establishing Communication.

10. In establishing communication, between the different parts of the instrument and the battery, copper wire insulated by cotton covered with varnish, or gutta percha, is made use of. The main wires, or those leading from the apparatus to the wire targets, may be either of copper or galvanized iron, supported on posts in the ordinary telegraphic manner, Fig. 4.

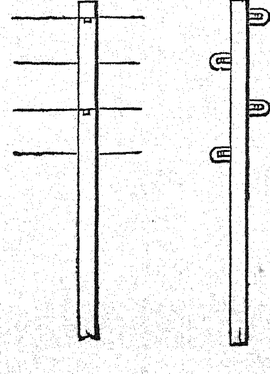


Fig. 4.

The circuits which it is necessary to establish are three in number; their direction is shown in Fig. 5.

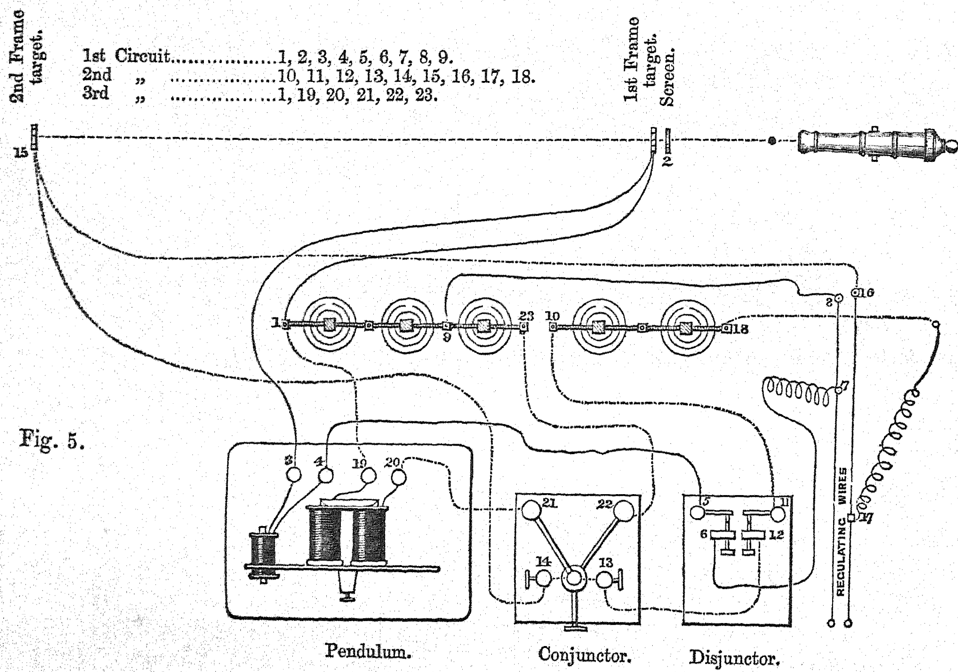


Fig. 5.

The first circuit includes the first wire target 2, the two pressure screws belonging to the straight electro-magnet of the pendulum 3, 4; the two pressure screws on the left of the disjunctor 5, 6, and the two poles of the larger battery 1, 9.

1st Circuit 1, 2, 3, 4, 5, 6, 7, 8, 9.

The second circuit includes the second wire target 15, the two pressure screws at the extremity of the rods on the conjunctor 13, 14; the two pressure screws on the right of the disjunctor 11, 12, and the two poles of the smaller battery 10, 18.

2nd Circuit 10, 11, 12, 13, 14, 15, 16, 17, 18.

The third circuit includes, the two pressure screws belonging to the large horseshoe magnet of the pendulum 19, 20; the two remaining screws on the conjunctor 21, 22; and the two poles of the larger battery 1, 23.

3rd Circuit 1, 19, 20, 21, 22, 23.

Thus the first and third circuit include the larger battery, and the second circuit the smaller battery; but the first and third circuits are never open at the same time, as the first circuit is always broken before the third circuit is made.

*Regulating the Currents.**

11. The communications having been established, the disjunctor is put upon cock, and the operator, by touching the two straight electro-magnets with a piece of iron, assures himself that the currents follow the required circuits. If he finds that both magnets are active, he is certain that this is the case; if one, or both of them, are not active he knows that there is a breakage somewhere in the communications, or that the batteries do not furnish a current of sufficient intensity. Supposing that both magnets be found active, the operator then causes the pendulum to oscillate, and proceeds to regulate the mercury in the little iron cup of the conjunctor, by turning the vertical screw-head till the mercury comes in contact with the point of the pin belonging to the steel blade; the moment the mercury touches the pin the third circuit is completed, the large horseshoe electro-magnet becomes active, and, by exerting a greater force upon the washer of the needle than the spring which presses this washer to the pendulum rod, clamps the needle.

The operator then turns the vertical screw-head back two whole revolutions, so that the circuit is again opened, the washer now is detached from the electro-magnet by taking its collar with the forefinger and thumb, and drawing it towards the operator's body.

12. These preliminary arrangements being completed, the pendulum is carefully raised to its initial position, supporting the rod on the first finger. If the pendulum bob is attracted *very strongly*, the battery must be reduced one element, by changing the points of attachment of the wire, Fig. 6.

The power of the electro-magnet is again tested, and the core withdrawn till the electro-magnet has not the power of holding the bob any longer, the core is then screwed back till the magnet just holds up the bob.

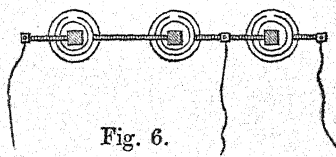


Fig. 6.

The core or piece of soft iron in each of the two straight electro-magnets is made to screw in and out, by this means the power of the magnet can be varied at pleasure.

13. Exactly the same arrangements are gone through in regulating the currents of the conjunctor, whose electro-magnet is just made powerful enough to overcome the effect of gravity, and hold up the leaden weight.

Trial of the Apparatus when Adjusted.

14. When the apparatus has been thus adjusted, a trial is made to see whether the instrument works correctly. To do this, it is sufficient to employ the instrument to measure a known time. If the time chosen be 0, the trial consists simply in operating, twice in succession, by means of the disjunctor.

* This operation used to be performed by means of regulating wires of platinum; in the instruments of the latest pattern the currents are regulated by means of screw cores in the straight electro-magnets of the first and second circuits.

The operator puts the disjunctor on cock, raises the pendulum with his forefinger to the electro-magnet, which retains it; the zero of the vernier coincides then with the zero on the limb. The operator then presents the weight to the electro-magnet of the conjunctor, which retains it; sometimes the weight oscillates round the point of suspension, the operator waits till these oscillations cease; then, pressing the trigger of the disjunctor, the ivory buffer strikes the springs, breaks both circuits together, and instantaneously demagnetizes both magnets at the same moment; the pendulum is set in motion, the weight falls, meets the steel blade, presses the pin into the mercury, completes the third circuit and instantly magnetizes the large electro-magnet, which clamps the washer and needle.

The operator then removes the weight from the blade, notes the angle marked by the needle, detaches the latter from the magnet, and proceeds to operate again with the instrument exactly in the same manner. The needle again marks an angle, which ought to be the same as that of the first operation; if there is a difference, it indicates the degree of regularity in the working of the apparatus. A practised experimenter may easily succeed in bringing the difference, between two successive operations, to a maximum of $0^{\circ}\cdot25$; and he is able to see immediately where the error lies, and knows at once the necessary corrections. *The angle which the needle marks denotes the time, occupied by the leaden weight in falling from its point of suspension to the steel blade.*

Employment of the Apparatus.

15. As soon as the operator is certain that the instrument works regularly, experiments may be proceeded with. The operator must bear in mind that the two operations, viz. that performed by means of the disjunctor, and that which takes place by the effect of the shot, must be made under identical circumstances. Suppose the instrument ready, the targets in their places, and the gun charged. The experimenter operates by means of the disjunctor, and reads off an angle which we will call A, Fig. 7; then having again put the disjunctor on cock, and placed the pendulum and weight in their initial positions, he gives the signal to fire. The gun is fired; the projectile passes through the first target, breaks the first circuit, and demagnetizes the straight electro-magnet of the pendulum; the pendulum, in consequence, is set in motion. The projectile then passes through the second target, breaks the second circuit, and demagnetizes the conjunctor electro-magnet; the weight falls, presses the pin into the mercury, completes the third circuit by which the large electro-magnet is made active, and the needle clamped. The operator reads the angle, which we will call A', and which is larger than A, for this reason, that instead of both currents being broken *simultaneously*, as is the case when operating with the disjunctor, they are now broken successively, as there is a certain distance between the

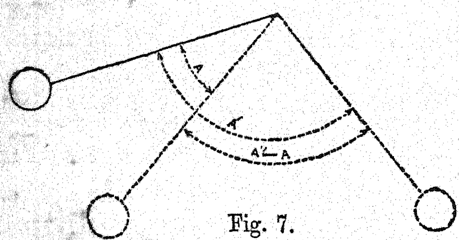


Fig. 7.

two targets, over which the shot must pass. The angle A' therefore denotes the time occupied by the falling of the weight, *plus the time occupied by the projectile in passing from the first target to the second.* Therefore the difference between these angles, or $(A'-A)$, corresponds to the time occupied by the projectile, in passing through the space included between the two targets.

This angle is converted into time, by employing a table, giving the times corresponding to the arcs passed through by the pendulum.

Calculation of the Table of Times.

16. This calculation is founded upon the duration of one very small oscillation of the pendulum. To obtain this datum, the whole oscillating system is suspended upon a support, Fig. 8. The pendulum is then made to

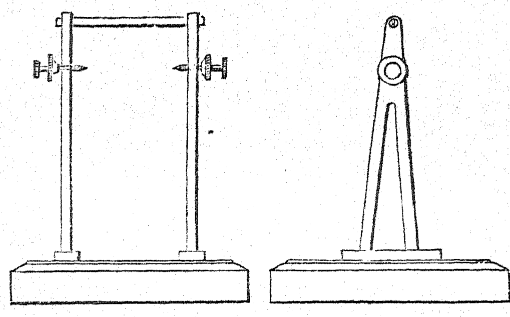
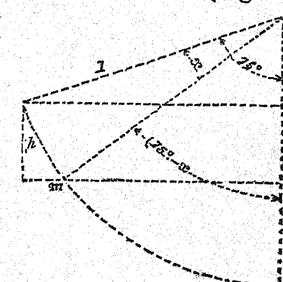


Fig. 8.

oscillate, and the time observed by a chronometer; this time divided by the number of oscillations, gives the time of one small oscillation of the pendulum. When this is known, it is easy to compute the time employed by the pendulum in describing any part of an oscillation. For (Fig. 9) calling l, the length of a pendulum beating the time t, of one very small oscillation; v the velocity of the centre of oscillation of the pendulum, or, the velocity of the point m, situated at a distance l, from the axis of suspension after a vertical descent h; x, the angle, variable with the point m; T, the time that the point m would take to move through a circumference whose radius is l, with a uniform velocity v.



Then $v = \sqrt{2gh}$.

Fig. 9.

17. By the common equation of the pendulum,

$$l = \frac{g}{\pi^2} t^2,$$

where t is the time of one small oscillation. But,

$$v = \sqrt{2gh},$$

and if a represent the constant angle of half-oscillation, and x the angle variable with h, we shall have

$$h = l\,\{\cos(a - x) - \cos a\};$$

therefore

$$v = \sqrt{2gl\,\{\cos(a - x) - \cos a\}},$$

$$\text{or} \quad v = \frac{gt}{\pi}\sqrt{2\{\cos(a - x) - \cos a\}}.$$

If T be the time occupied by the pendulum l, in describing a whole revolution, the motion being supposed to be uniform,

$$T = \frac{2\pi l}{v},$$

$$\text{or} \quad T = \frac{2t}{2\sqrt{\{\cos(a - x) - \cos a\}}}.$$

And, in general, if T be the time which the pendulum takes to pass through an arc contained K times in the circumference,

$$T = \frac{2t}{K\sqrt{2\{\cos(a - x) - \cos a\}}},$$

But in Navez's apparatus the constant angle of half-oscillation $= 75^\circ$; therefore

$$T = \frac{2t}{K\sqrt{2\{\cos(75^\circ - x) - \cos 75^\circ\}}}.$$

The values successively given to x correspond to the middle of each arc; thus in calculating a table when the arcs are made equal to 1°, the values of x are made $\frac{1}{2}^\circ$, $1\frac{1}{2}^\circ$, $2\frac{1}{2}^\circ$, &c., and it is assumed that each arc is passed through with a velocity equal to that acquired in the middle of the arc. This method of calculation of Major Navez is not *strictly* correct, but the small loss of time resulting from his method never affects those arcs comprised in the space $(A' - A)$, and may practically be considered *nil*. Tables calculated by this means will be found in Captain Noble's Report, Appendices III. and IV. pp. 148, 149.

Description of the arrangements at Shoeburyness for carrying on experiments with Navez's Electro-Ballistic Apparatus.

18. The instrument room at Shoeburyness is constructed in the lower story of the tower, used in supplying the barracks with water. No pains have been spared to make this room as complete as possible. It is lighted by three large windows, and has a stove in which a fire is

constantly kept. The table, on which the instruments stand, is of very solid construction, and rests upon a large solid flagstone embedded in concrete, and perfectly insulated from the flooring. At each side of this table smaller tables are constructed, the greatest care being taken that they do not touch the large table. The room is furnished with presses, tables, shelves, and all the necessaries of an instrument room. A barometer and thermometers of the very best construction, serve to denote the atmospheric changes.

19. The voltaic batteries are arranged on small shelves in an outer room, and the connecting wires between the voltaic batteries and the several parts of the instrument, as well as from the instrument and batteries to the main wires, are copper wires of 0·05 in. diameter, insulated with gutta percha. The main wires consist of ordinary galvanized iron wire of 0·16 in. diameter, stretched on posts to the targets.

20. The gun battery is at a distance of 225 ft. from the instrument room. The battery consists of two platforms laid parallel to one another at a distance of 10 ft. apart. In front of these platforms screens are placed, at a distance of 20 ft. These screens are of the most solid construction, and faced with sheet iron; a slot, and movable slider, serves to regulate the size and height of the hole through which the projectile has to pass. At 2 ft. in front of each platform pickets are driven into the ground, and all measurements with regard to the distance of the targets are made from these pickets; in practising, the muzzle of the gun is brought over the picket.

21. From each picket a horizontal distance of 150 ft. is accurately measured, following a line perpendicular to the hurter of the platform; at the extremity of this distance a flagstone is firmly set in concrete, and a line drawn on the stone marking the distance; from this flagstone a horizontal distance of 120 ft. is set off towards the platform, and another flagstone set; the targets rest on these flagstones. The first target is therefore at a distance of 30 ft. from the picket, and the second target at 120 ft. from the first, and at 150 ft. from the picket; the point midway between the targets is therefore 90 ft. from the picket. Both ranges are parallel, and exactly the same, and, as has been stated, at a distance of 10 ft. from each other.

22. Other flagstones are placed at intermediate distances, so that the targets can be moved to within 60 ft. of each other when operating with small charges, and consequently low velocities.

23. A line of posts, bearing the wires, comes from the instrument room to the first target, and the wires are then continued by a post to the second target.

24. The targets consist of two parts, the frame, and the target.

The frame is formed of wood, in the manner before described (Sect. 9); and the targets can be hung up on the frame, by means of hooks and eyes. The targets are made of very hard wood and are 30 by 40-in., a row of hard wooden pins, 1·5 in. apart, are driven into the sides of the

target; the whole face is then coated with shellac, and covered over with silk, and afterwards given two or three coats of shellac, this insulates the pins perfectly. Two little double pressure screws insulated in ebonite are inserted in the frame. When the targets are required for use, the wire is stretched across them by means of the pins, a short piece being left at each end. The targets are then hung on the frames, and the ends of the wire put in communication with the double pressure screws; if these screws are also placed in communication with the main wires, the current will circulate through the wire on the target. When the wires of a target have been broken by the passage of a shot, it is detached from the frame, and a fresh target substituted.

25. Several methods of construction have been adopted with regard to these frame targets, and the last seems to have given as much satisfaction as any, and is much the cheapest, viz.: the frame is constructed of common deal, and the pins are formed of screws run through a little piece of gutta percha tubing.

26. In order to ascertain the remaining velocity of projectiles, the following arrangements have been made:—

The line perpendicular to the hurter of the platform has been produced and carefully measured to over 1000 yds., all the measurements being horizontal.

Different ranges have been established on this line at the several distances from the gun of 200, 400, 600, and 1000 yds. Upright posts are sunk in the ground at these different distances, the posts are about three feet high, and serve as supports for the movable posts to which the wire targets are hung.

The targets used at these long distances are from 6 to 9 feet square.

Thus, let us suppose the range to be 200 yds., or that it is required to estimate the velocity of the projectile at a point 600 ft. from the muzzle picket.

The first pair of pickets are set at 540 ft. from the picket, one on each side of the perpendicular line and at about three feet from it, leaving therefore about 6 ft. between the uprights.

The second pair of posts are set in the same manner, at 120 ft. from the first pair, and, therefore, at 660 ft. from the picket; so that the middle point between both pairs is 600 ft. or 200 yds. from the picket,

The other ranges are completed in the same manner.

The space of 120 ft. may be reduced by placing other intermediate uprights.

The wires are carried on posts in the ordinary manner to the 200 yds. range; after that the wires are laid under ground, being perfectly insulated with indian-rubber and tarred hemp.

The cable for this purpose was made by Messrs Wells and Hall, of Mansfield Street, London, and has given much satisfaction.

The cable passes through a station, opposite each range, in which there is a disconnecting apparatus; by this arrangement the wires in the cable can be put in communication with the target on any range down the line. The stations are formed of hollow cast-iron cylinders with screw caps.

27. In addition to the foregoing arrangements, a small portable wooden hut has been constructed, in order that the instrument may be moved from place to place, Fig. 10.

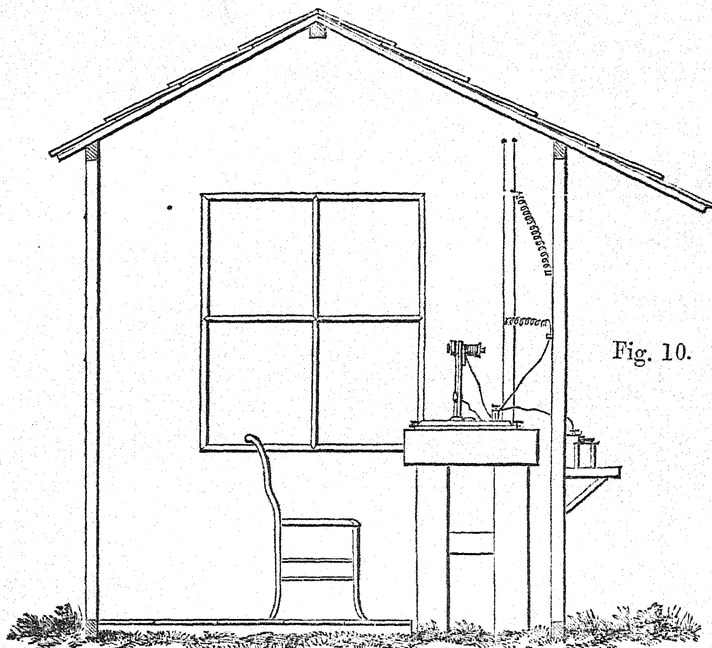


Fig. 10.

The hut has a half-flooring, and the table on which the instrument rests, stands upon the natural ground, without touching the hut. A movable cable has also been constructed to accompany this hut. This cable unrolls itself off a travelling axle, and can lie on the ground while the ends are attached to the frame targets and the instrument.

I have found this arrangement of the greatest use, as the instrument can be moved to any gun which may happen to be of such a size, or in such a position, as to make its removal inconvenient.

28. I have had considerable experience in the use of Major Navez's delicate and beautiful little instrument, and can speak from personal knowledge of its great accuracy when skilfully manipulated.

The following are the chief points to be attended to :—

Any error in the adjustment of the pendulum is easy of correction; the principal thing to be looked to being the distance of the washer from the poles of the large electro-magnet, and the amount of play allowed to the oscillating system. This has been explained already.

Of course every part of the instrument must be kept quite clean, and free from dust or grit.

In the disjunctor care must be taken that the platinum pointed screws are near enough to one another, and that when the instrument is cocked one blade is not in advance of the other.

The chief source of error lies in the conjunctor; *the mercury must be perfectly pure,* and during a long day's experiments it would be well to change

this once or twice, as it becomes more or less covered with an oxide, owing to the spark caused by the disruption of the current when the leaden weight is taken off. It sometimes happens also, unless care be taken, that some of the mercury splashes out of the little cup when the weight falls.

This weight should have a hemispherical bottom; and when it gets flattened, by constant falling on the steel blade, it should be rubbed against a piece of sand paper held in the hollow of the hand; a mixture of lead and antimony is the best material of which to make this weight. All the several connexions should be kept well polished, and the insulation of the wire targets complete.

I have sometimes found a target become uninsulated by being spattered with the grease contained in the lubricating wads, used with rifle guns. Care must be taken that all the pressure screws bite the wires firmly; the action of the disjunctor sometimes loosens the pressure screws on that instrument.

The table should be truly level, the instrument carefully levelled, and the pendulum adjusted in the half-arc of oscillation.

There must be no friction of the vernier against the limb, and the tension of the forked spring must be nicely regulated.

The resistances in the first two circuits should be as fine as possible, and the battery which supplies the currents should be in perfect trim, *well amalgamated*, and the acid *fresh and good*. The batteries should be prepared at least a quarter of an hour before using the instrument.

The operator must bear in mind that he is conducting a philosophical investigation which requires skill and care in order to render the results trustworthy.

Use of the Table.

29. The following is an application of the calculation, and the manner of employing the table;* the vernier reading $0^{\circ}\cdot05$.

110-pr. ARMSTRONG GUN.

Instrument 32.

A', or arc obtained by firing	$= 109^{\circ}\cdot05$
A, or arc obtained by disjunctor	$= 41\cdot60$
To obtain the time corresponding to the arc A', the number corresponding to the 109th degree is sought in the column "Total Durations," and found ...	$= 0''\cdot240650$
To this must be added the time corresponding to ·05 of the 110th degree; the "Partial Duration" corresponding to the 110th degree is $0''\cdot001743$; multiplying this by ·05 we obtain	$= 0''\cdot000086$
	$A' = 0''\cdot240736$
Proceeding in the same manner to obtain the time corresponding to the angle A, we find,	
For 41° .... $0''\cdot132592$	
For ·60 .... $0\cdot001728 \times \cdot60 = 0''\cdot001036$	
	$A = 0''\cdot133628$
Difference $= (A' - A)$	$= 0''\cdot107108$

To calculate the velocity of the projectile from the time obtained by the instrument, it suffices to divide the distance between the two targets by this time, to give the velocity of the projectile at a point in the trajectory equidistant between the targets. Supposing the targets to be 120 ft. apart, and

* *Vide* Captain Noble's Report, Appendix IV. p. 149.

the time obtained 0″·107108, the velocity of the projectile v, at the equidistant point is

$$\frac{120}{0\cdot107108} = 1120\cdot4 \text{ feet},$$

and as the first target was at a distance of 30 ft. from the muzzle of the gun, 1120·4 is the value of v at 90 ft. from the muzzle.* This velocity must be corrected to that which it would have been at the muzzle.

30. The initial velocity of a projectile has been calculated from several different formulæ. The one which has been used in the experiments with Navez's electro-ballistic apparatus at Shoeburyness is

$$1 + \frac{r}{v} = \left(1 + \frac{r}{V}\right) e^{\frac{x}{2c}},$$

in which x is the distance from the muzzle of the gun to where the velocity is v. The value of r is constant and equals 1427 ft., and the ballistic coefficient c is given in the following tables for all descriptions of ordnance.

This coefficient is calculated according to Didion's law of resistance, which, as before stated, is open to correction. However, within short distances it may be assumed as *practically* correct.

I.

Table giving the value of the Ballistic coefficient C for English projectiles.

SMOOTH BORES.

Ordnance.	Projectile. Nature.	Projectile. Mean weight including bursting charge, fuze, &c.	Projectile. Mean diameter.	Value of C in feet.	Remarks.
		lbs.	in.		
68-pr.	Shot	66·520	7·91	5870·0	The values of C have been calculated from the formula $C = \frac{1}{2g} \frac{P}{A\pi R^2}$, $g = 32\cdot1908$ ft., $A = 0\cdot0005137$, $\pi = 3\cdot1415926$, $2R$ = diameter of shot, P = weight of shot.
32-pr.	”	31·375	6·17	4569·0	
24-pr.	”	23·500	5·60	4154·3	
18-pr.	”	17·687	5·09	3784·6	
12-pr.	”	12·625	4·52	3425·7	
9-pr.	”	9·370	4·10	3090·1	
6-pr.	”	6·245	3·57	2716·4	
10-in....... } 68-pr. ... }	Com. shell	92·625	9·84	5303·2	
8-in.........	”	49·875	7·86	4475·5	If projectiles differ much in weight from the weights given in the Tables, it will be sufficient to multiply C by the ratio of the weights. $C' = C\frac{P'}{P}$.
32-pr.	”	24·312	6·17	3540·4	
24-pr. ... } 5½-in....... }	”	17·500	5·59	3099·1	
18-pr.	”	13·125	5·09	2808·4	
12-pr. ... } 4⅖-in....... }	”	9·000	4·45	2515·0	
8-in.........	Diaphragm shell	60·750	7·91	5382·6	
32-pr.	”	28·750	6·17	4186·6	If the diameter differs in the inverse ratio of the squares, $C' = C\frac{R^2}{R'^2}$.
24-pr.	”	20·875	5·59	3696·8	
18-pr.	”	15·875	5·09	3396·8	
12-pr.	”	10·375	4·45	2898·6	
9-pr.	”	8·060	4·08	2684·2	
6-pr.	”	5·125	3·56	2241·8	

* This is not mathematically correct, but the error is so very minute that practically the computed velocity may be assumed to be that at the middle of the distance between the two targets.

II.

Table giving the value of the Ballistic coefficient C for rifled Projectiles.

Nature of Ordnance.	Projectile. Nature.	Mean weight.	Mean diameter.	Value of C in feet.	Remarks.
		lbs.	ins.		
Armstrong 110-pr.	Shot	111·60	7·00	18938·4	The values of C have been calculated from the formula
„ „	Shell	103·80	„	17614·8	$C = \frac{1}{2g} \frac{P}{A \pi R^2}$, $g = 32·1908$, $A = 0·0003425$,
„ 40-pr.	Shot	41·50	4·75	15293·9	$\pi = 3·1415926$, $2R$ = diameter of shot, P = weight of shot.
„ 20 „	„	21·20	3·75	12535·7	If projectiles differ much in weight from the weights given in the Table, it
„ 12 „	S. Shell	11·75	3·00	10856·0	will be sufficient to multiply C by the ratio of the weights,
„ 9 „	„	9·25	3·00	8546·2	$C' = C \frac{P'}{P}$, If the diameters differ in the inverse ratio of the squares,
„ 6 „	Shot	6·25	2·50	8315·3	$C' = C \frac{R^2}{R'^2}$.

31. Supposing the targets to have been 120 ft. apart, and the distance from the muzzle to the first target 30 ft., the point x will be situated at 90 feet from the muzzle.

In the example chosen, the velocity at this point will be 1120·4 ft., the gun being the 110-pr. Armstrong.

Looking in the Table for the value of C, it is found, viz. 18938·4, which multiplied by 2, equals 37876·8.

The equation then becomes

$$1 + \frac{1427}{1120·4} = \left(1 + \frac{1427}{V}\right) e^{\frac{90}{37876·8}}$$

$$\frac{90}{37876·8} = 0·002376,$$

$$1 + \frac{1427}{1120·4} = \left(1 + \frac{1427}{V}\right) e^{0·002376}.$$

$$2·27365 = \left(1 + \frac{1427}{V}\right) e^{0·002376}.$$

The value of $e^{0·002376}$ is obtained by developing the series,

$$e^{x'} = 1 + \frac{x'}{1} + \frac{x'^2}{1.2} + \frac{x'^3}{1.2.3} + \&c.$$

$$e^{0·002376} = 1 + \frac{0·002376}{1} + \frac{0·002376^2}{1.2} + \frac{0·002376^3}{1.2.3} + \&c.$$

$$= 1 + 0·002376 + 0·000002823 + 0·000000002 + \&c.$$

The fourth term of the series may be safely neglected, and we find

$$e^{0·002376} = 1·0023788,$$

$$2·27365 = \left(1 + \frac{1427}{V}\right) 1·0023788,$$

$$2{\cdot}27365 = 1{\cdot}0023788 + \frac{1427 \times 1{\cdot}0023788}{V},$$

$$2{\cdot}27365 - 1{\cdot}0023788 = \frac{1427 \times 1{\cdot}0023788}{V}.$$

$$V = \frac{1427 \times 1{\cdot}0023788}{1{\cdot}2712712}$$

$$= 1125{\cdot}2.$$

That is to say, in passing over the first 90 ft. of air, the 110-pr. solid shot loses 4·5 ft. of the velocity with which it started. Of course the truth of this theorem depends almost entirely upon the value given to the ballistic coefficient C, and this latter depends upon the value of the constants A and r. I have taken these constants according to Didion's law of the resistance, which perhaps is still capable of correction;* however, at present, it is the best and most accurate law we know, and at short distances, the results obtained by it may be considered correct.

III.

Table shewing the Times corresponding to the Arcs for Instrument No. 32, the time of a small Oscillation being = 0·3337 seconds.

Arc.	Total Duration.	Partial Duration.	Arc.	Total Duration.	Partial Duration.	Arc.	Total Duration.	Partial Duration.
°			°			°		
30	·112397	·001945	65	·171342	·001536	100	·225546	·001633
31	·114342	·001919	66	·172870	·001533	101	·227179	·001643
32	·116261	·001895	67	·174413	·001531	102	·228823	·001653
33	·118156	·001872	68	·175944	·301529	103	·230476	·001664
34	·120028	·001851	69	·177474	·001527	104	·232141	·001676
35	·121879	·001830	70	·179002	·001525	105	·233817	·001688
36	·123710	·001811	71	·180527	·001524	106	·235506	·001701
37	·125521	·001793	72	·182052	·001523	107	·237207	·001714
38	·127314	·001775	73	·138576	·001522	108	·238922	·001728
39	·129090	·001759	74	·185098	·001522	109	·240650	·001743
40	·130849	·001743	75	·186621	·001522	110	·242393	·001759
41	·132592	·001728	76	·188144	·001522	111	·244153	·001775
42	·134321	·001714	77	·189667	·001523	112	·245928	.001793
43	·136035	·001701	78	·191190	·001524	113	·247721	·001811
44	·137737	·001688	79	·192715	·001525	114	·249533	·001830
45	·139425	·001676	80	·194241	·001527	115	·251363	·001851
46	·141102	·001664	81	·195768	·001529	116	·253214	·001872
47	·142766	·001653	82	·197298	·001531	117	·255086	·001895
48	·144420	·001643	83	·198830	·001533	118	·256981	·001919
49	·146063	·001633	84	·200364	·001536	119	·258901	·001945
50	·147697	·001624	85	·201900	·001540	120	·260846	·001972
51	·149321	·001615	86	·203441	·001543	121	·262818	·001999
52	·150937	·001607	87	·204985	·001547	122	·264818	·002030
53	·152544	·001599	88	·206537	·001551	123	·266849	·002062
54	·154144	·001592	89	·208084	·001556	124	·268912	·002097
55	·155737	·001585	90	·209641	·001561	125	·271009	·002134
56	·157322	·001578	91	·211202	·001566	126	·273144	·002173
57	·158901	·001572	92	·212769	·001572	127	·275318	·002215
58	·160473	·001566	93	·214342	·001578	128	·277534	·002261
59	·162040	·001561	94	·215920	·001585	129	·279795	·002310
60	·163602	·001556	95	·217505	·001592	130	·282106	·002363
61	·165158	·001551	96	·219098	·001599	131	·284469	·002421
62	·166710	·001547	97	·220698	·001607	132	·286891	·002484
63	·168258	·001543	98	·222306	·001615	133	……	……
64	·169201	·001540	99	·223921	·001624			

* Experiments are being made, under the directions of the Ordnance Select Committee, to determine the laws of the resistance of the air to the motion of projectiles; and up to the present time there is reason to believe that General Didion's coefficients are nearly correct for rifle projectiles, but that they are too small for spherical shot of large calibre.

THE FOLLOWING EXPERIMENT TOOK PLACE AT SHOEBURYNESS, ON THE 16TH AND 25TH SEPTEMBER, 1862, IN ORDER TO TEST THE PENETRATING POWER OF THE HORSEFALL GUN.*

Weight of gun, 24 tons 3 qrs. 2 lbs. 2·21 oz. Diameter of bore, 13·014″. Windage,† ·2.

THE target (10′ × 12′) was of the "Warrior" construction, without a porthole. The plates, which were tongued and grooved, and which had been manufactured at the Parkhead forge, were of the following dimensions, viz.: upper one 12′ × 3′ × 4·5″; centre one 12′ × 3′ 8″ × 4·5″; lower one 12′ × 3′ 4″ × 4·5″.

Range, 200 yds. Charge, 74·40 lbs. Solid cast-iron shot, weight 279·50 lbs. Initial velocity 1631 ft.

Struck the centre plate about 1′ from the top and 5′ from the left side. The shot completely penetrated the target, making an irregular hole in the armour-plate 2′ 1·5″ × 2′ 4″, and breaking off 1′ of the tongue at the top of the plate; a large crack ·7″ wide extended from the bottom of the hole to the bottom of the plate; also three narrow cracks, one 8″ long running from the large one, parallel to the circumference of the hole, the other two radiating from the hole, at a distance of 1′ and 1·5′ from the large one, the latter being 15″ long and running into a bolt-hole. Three bolts had started in the centre plate, two of them ·6″ and one ·2″. Four bolts in the upper plate and one in the lower plate also started. The upper plate was forced up ·4″ for a quarter its length from the left side. There was no buckling of the plate. At the back, portions of shot and plate were buried deeply into a timber bulkhead three feet in rear; five bolt-heads broken off; two ribs broken completely through, one being driven out, and 2′ 4″ of the other detached; and a third rib was cracked through a rivet-hole for a length of 4″. About three square feet of the interior skin driven in, more than twenty bolts broken, and the skin much shaken, bulged, and opened at the joints. Two of the front baulks of the timber backing forced up at the top 1″ and ·5″ respectively.

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* Defects in Horsfall gun, taken from the Report of the Inspector of Artillery:—

A plug (8·4″ diameter) is inserted in the bottom of the bore (driven back ·05″ after the experiment of the 16th September, 1862).

Right.—A hole, 1·8″ long, ·65″ wide, and 13·75″ deep, extends from the edge of the plug; another 1·5″ from the edge of the plug, is ·55″ long, ·25″ wide, and ·2″ deep.

Left.—A hole from the edge of the plug, ·5″ long, ·5″ wide, and 3·75″ deep; another, 1·5″ from the edge of the plug, ·8″ long, ·3″ wide, and 5·75″ deep. (Dimensions of this flaw, after the experiment of the 16th September, ·65″ long, ·35″ wide, and 6·5″ deep).

Left of down.—One hole at the end of the bore, ·5″ long, ·15 wide, and ·1″ deep.

In the bottom of the bore a flaw commences at the edge of the plug, about ·2″ wide and ·2″ deep at the largest part, and extends 25″ along the bore (this flaw has slightly increased in size).

In addition to these flaws, small longitudinal fissures, such as are usually found in wrought-iron ordnance, are visible all round the bore at 35″ from the breech.

† Taken from the Report of the Ordnance Select Committee, 5th February, 1857.

On the gun being thoroughly cleaned and examined, it was found that one of the flaws which existed in the bore of the gun previous to this experiment had slightly increased.

September 25th.

Range 800 yds. Charge 74·40 lbs. Solid cast-iron shot * mean weight 284 lbs. 13 oz. Velocity at 780 yards 1299·2.

The same target was used as on the 16th of September.

New shot were made for this experiment, whereby the windage was reduced to ·1305.

1st round. Missed the target; the shot struck the masonry some yards to the left. Elevation 57′.

2nd round. Elevation 1°. The shot grazed 17 yds. 1 ft. in front of the target, which it struck at the junction of the middle and lower plates 3′ from the right side, making an irregular hole 2′ × 1′ 11″ in the armour-plate; the shot broke up and was buried in the backing, the depth from the surface of the plate to the broken shot being 1′; the lower plate was forced down 1·3″ from the hole to the right side, and the centre plate had started to the front 1·2″ at the bottom, between the hole now made and the one made at the last experiment; cracks already on the plate much opened, and several new ones (one being 1′ 9″ long) made on the centre plate. At the back two ribs broken completely through, one being driven in 4″, and a length of 2′ of the other doubled back, and resting on the ground; the skin considerably bulged out and opened at the joint, but not cracked; four bolts and one rivet driven out some inches, and three bolt-heads broken off. No buckling of the plate.

3rd round. Elevation 1° 5′. Missed the target and penetrated the backing of the old "Warrior" target some yards to the right; did great havoc on brickwork, wood supports, &c. in the rear, some large pieces of wood being picked up 60 yds. in rear.

4th round. Elevation 1° 2′. The shot struck the left top corner of the upper plate, and broke off a piece of plate measuring 2′ horizontally × 1′ 6″ vertically; no cracks on the plate; one bolt driven out, and one started 2·5.″ The backing and skin at the top of the target very much shaken. The skin forced back 8″ (in the greatest depth) for a length of 4′, and the damage extended down the target for 5′ from the top; the front baulks of the backing forced out for a depth of 2′ 1″ from the top, and three of the rear baulks much splintered. The outer rib broken through vertically for a length of 2′ 6″ from the top, and doubled up 4″, only now measuring 6″ in depth.

No increase in the flaws in the gun after this day's firing.

One round of solid cast-iron shot was fired from a 68-pr. 95 cwt. gun, at 200 yds. range, at the left side of the lower plate, to test the quality of the metal, and made an indent of 4·05″; two large and two small cracks on the face of the indent, and large cracks on the plate parallel to the circumference of the indent, and 5″ below it, extending upwards for 1′ on each side. The iron was very brittle, irregular, and largely crystalline, and seemed unfit for armour plates.

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* These shot had been annealed and were very tough.

The following Experiment was carried on to test the penetrating power of
and further to ascertain whether Shell could be

Number of round.	Nature and weight of ordnance.	Projectile. Nature.	Projectile. Weight.	Projectile. Bursting charge of shells.	Projectile. Form.	Projectile. Length.	Charge in lbs.	Diameter of bore. From face to face.	Diameter of bore. From angle to angle.	Windage on going in half sides.	Turn of rifling.	Range in yards.	Thickness of plate.	Elevation.	Deflection.	Initial velocity in feet.
			lbs. oz.	lbs. oz.												
	12-pr. breech-loader. $9\frac{3}{4}$ cwt.	...	12 1	...	...	7″	...	2·73″	3″	·02365	1 in 55″	200	...	...	...	...
1	,,	Solid shot.	12 1	...	Cylindrical flat-ended.	...	1 14	...	...	...	...	,,	2·5″	...	...	...
2	,,	Shell.	12 $2\frac{1}{2}$	0 6	...	...	1 14	...	...	...	...	,,	2·	...	...	...
3	,,	,,	...	...	...	...	1 12	...	...	...	...	,,	2·	...	...	...
1	70-pr. Whitworth muzzle-loading rifled gun, 76 cwt. 2 qrs. 14 lbs.	,,	68 8	2 6	...	16″	12 0	5″	5·5″	·035	1 in 100″	,,	...	...	...	1275·8
																Veloc. at 580 yd.
1	120-pr. muzzle-loading rifled gun, 148 cwt. 3 qrs.	Solid shot.	120 6	...	Round ended.	14″	20 0	6·4″	7·″	·06	1 in 130″	600	...	45′	0	...
2	,,	,,	131 10	...	Flat-ended.	,,	20 0	,,	,,	,,	,,	,,	...	55′	0	...
3	,,	,,	,,	...	,,	,,	23 0	,,	,,	,,	,,	,,	...	,,	5′ R.	...
4	,,	Solid shot. Homogeneous metal.	129 0	...	,,	,,	23 0	,,	,,	,,	,,	,,	...	47′	6′ R.	1278·5
5	,,	Shell. Homogeneous metal.	130 0	3 8	,,	17″	25 0	,,	,,	,,	,,	,,	...	45′	,,	1268·0

Whitworth Projectiles fired from a 12-pr., a 70-pr., and a 120-pr. gun; made to explode after penetrating Iron Plates.

Remarks.

One round was fired with solid cast-iron shot to obtain the range, and the shot and shell used in the experiment were made of homogeneous metal, hardened and tempered. The firing (with solid shot) was at a 2·5″ plate, without backing, secured to a wooden frame; and with the shell at a 2″ plate backed by 12″ of wood; the dimensions of the plates were 4′ 3″ × 3′ × 2·5″, and 5′ 6″ × 2′ 6″ × 2″. No fuze was used with the shell.

1. Passed through the plate and fell 20 yds. to the rear. A clean hole in front 3·2″ × 3·1″, and at the back the diameter of the hole was 6·5″ × 6″, the plate being broken for about 1″ round the edge of the hole, and piped out about 1·5″ in the centre. The shot set up ·5″.

2. Passed through the plate and backing, making a clean hole in the plate of 3·1″ × 3″ diameter. There was, however, no trace of the shell having burst.

3. Passed through the plate and backing, making a clean hole 3·4″ × 3·1″, and shell burst after passing through the backing.

1. This gun was fired at a box-target made of 4″ wood, with a 4″ armour-plate (made at the Thames Iron works) in front backed by 9″ of wood, and a 2″ armour-plate in the rear (made at Portsmouth Dockyard) as a guard plate, the interior space of the box being 36″ × 40″. One round with solid cast-iron shot was fired in order to get the range; it passed through a thin wooden target, and struck a damaged 5·5″ plate (one belonging to the "Minotaur" target) and broke it in two. The first shell fired penetrated into the box-target, making a hole in the 4″ armour-plate 5·6″ × 5·4″, and exploded on the rear plate, blowing out the sides of the box, and forcing the front and rear plates outwards. The rear plate was deeply indented (viz. 2·6″) but not penetrated. The shell broke into large pieces.

September 25th.

Trial shots for range fired at a wooden target 9′ × 9′, indicating great precision in No. 2 and 3 shots striking within a short distance of each other.

4. Fired at the "Warrior" target; struck the centre plate 2·5′ from the left and 1·5′ from the top, made a clean hole in the plate 8″ × 8·5″, the edge of the hole being 1′ 8″ from the one made by the first shot from the Horsfall gun; a narrow crack from one hole to the other; the shot remained in the hole, having struck on a rib, the depth of the hole to the bottom of the shot being 13·5″; no bulge on the plate; one bolt in the centre plate started ·4″, and two bolts started in the upper plate. The centre plate had started out ·3″ at the top, and ·1″ at the bottom on the left side. At the back, one rib which had been cracked by a shot from the Horsfall gun was broken through, bulged out, and a length of 1′ 6″ of it nearly detached; the wood backing splintered and broken; the skin opened about 1·5″ at the joint, and some additional bolt-heads broken off.

5. Struck the centre plate 1′ from the bottom and 1′ 4·5″ from the right side; penetrated the target, making a hole 8·5″ × 7·5″ in the plate, and burst in passing through the backing; two cracks on the plate, viz., one from the bottom of the hole to the bottom of the plate, and the other from a bolt-hole (1′ from impact) to the bottom of the plate; two bolts in the centre plate started ·5″, and one in the lower plate ·2″. At the back the diameter of the hole was 13″, and portions of the shell, and the piece of iron punched out of the plate, were picked up inside the target; some old oakum on the ground was on fire; three bolt-heads and one rivet-head broken off just above the hole; the skin not injured except where penetrated; the outer rib was broken through for a length of 4·5″. The timber backing much shattered, and driven out at the side 7″. The shell burst into about fourteen pieces.

Opinion of the Committee.

The experiment with the Horsfall gun, which was to test the endurance of this piece of ordnance, shows that solid wrought-iron guns of great size may be manufactured capable of bearing large charges of gunpowder; although this gun had several flaws in the breech, one 13-in. deep, as before described, yet these flaws have been very slightly altered by the firing.

The smashing effect of a spherical shot of 280 lbs. weight, fired with a charge of 74 lbs. of powder, was what might have been anticipated, and the accuracy of the gun was as good as that of any well-made smooth-bore piece of ordnance.

The experiments with the Whitworth guns were extremely satisfactory.

The 12 lbs. solid shot, fired with a charge of 1 lb. 14 oz., at a range of 200 yds., penetrated a 2½-in. wrought-iron plate, and remained unbroken.

A shell, with a bursting charge of 6 oz., was next fired from the 12-pr. gun, with the same charge and at the same range, at 2-in. of wrought-iron backed by 12-in. of wood; it passed completely through the target, buried itself in the sand-hill in the rear, and has since been dug up, when it was found not to have burst.

The charge was then reduced to 1 lb. 12 oz., and one fold of the flannel covering the bursting charge taken off, and the second shell passed through the target and burst in the rear.

The 70-pr. Whitworth gun was next fired at 200 yds. range. A shell from this gun, weighing 68 lbs. 7 oz., with a bursting charge of 2 lbs. 6 oz., was fired with 12 lbs. of powder at an iron case presenting a front of 7 ft. × 4 ft., covered with a 4-in. wrought-iron plate on a backing of 9-in. of wood, the rear of the box consisting of 4 in. of wood covering a 2-in. iron plate. The shell passed unbroken through the 4-in. plate, the 9-in. of wood and the 4-in. of wood, indented and cracked the 2-in. plate, and then burst, shattering the box into fragments.

The 120-pr. Whitworth gun was fired from a 600 yds. range, at a target representing the side of the "Warrior." A solid shot weighing 129 lbs., and fired with a charge of 23 lbs. of powder, penetrated the armour-plate and wood backing, and fractured, but did not pass through, the skin.

A shell weighing 130 lbs., with a bursting charge of 3 lbs. 8 oz., was fired with a 25 lb. charge at the same target. It penetrated the armour plate, and burst while passing through the wood backing, injuring and penetrating the skin in a line with the axis of the shell.

It must be remarked also that these projectiles, though flat-ended, were fired with great accuracy, and were much truer in their flight than any flat-ended projectile which the Committee have hitherto seen fired.

The results above recorded were obtained partly by using a larger charge of powder in proportion to the weight of the projectile than has hitherto been used in any rifled ordnance; but the great merit due to Mr Whitworth on this occasion seems to be in the successful manufacture of a metal possessing such hardness and temper as to be capable of penetrating wrought-iron plates, yet at the same time so tough as not to crush or break on striking the target. On no previous occasion have the Committee seen a shell of any description penetrate more than one inch of iron without breaking up on impact,

nor have they seen cast-iron or steel shot fired through more than two inches of iron without the shot itself being broken by the blow; wrought-iron shot have been fired through plates as thick, but though unbroken they have been crushed and distorted by the impact.

The Committee cannot conclude this report without commenting on the very inferior character of the $4\frac{1}{2}$-in. plates of which this "Warrior" target was composed. They were from Parkhead forge, near Glasgow, and are said to be of the number of those made for the "Black Prince." They were very brittle, and not sufficiently worked; and the measure of their inferiority may be recorded by stating that, with the service smooth-bore 68-pr. at 200 yds. and 16 lbs. of powder, the effect upon the old "Warrior" target, and upon other good $4\frac{1}{2}$-in. plates, was an indentation of about 2·5 in.; whereas the same test upon this target produced an indentation of 4·05, with considerable damage in the vicinity of the blow. The Committee deem it right to state that they believe the experiment with the Whitworth gun here recorded should be repeated, with as little delay as possible, on a target constructed of more satisfactory material.

The Committee would further recommend that the Whitworth solid shot and shell should be tried at an angular target, in order to ascertain the effect of homogeneous projectiles on plates placed at different angles to the horizon.

THE FOLLOWING EXPERIMENT WAS CARRIED ON AT SHOEBURYNESS, ON THE 13TH NOVEMBER, 1862, WITH WHITWORTH PROJECTILES, FIRED FROM THE SAME GUNS AS THOSE USED DURING THE EXPERIMENTS OF THE 16TH AND 25TH SEPTEMBER, 1862.

[CONTRIBUTED BY CAPTAIN E. J. BRUCE, R.A.]

A box target, measuring 12′ × 9′ 6″ and having an interior space of 10′ × 6′, was constructed for the experiment, and was composed of three armour-plates; the upper one, which was 4·5″ thick, had been used in the original "Warrior" target, and the centre one and lower one (each 5″ thick), were taken from Mr Samuda's target. The thickness of the backing and skin was the same as in the "Warrior" target.

Number of round.	Nature of ordnance.	Projectile.				Charge in lbs.	Bursting charge of shells.	Elevation.	Range in yards.	Deflection.	Effects.		Length of cartridge.	Velocity at 780 yds.	Remarks.
		Nature.	Weight in lbs.	Form.	Length.						Depth of indent in inches.	Diameter of indent in ins.			
							lbs. oz.	° ′							
1	120-pr *	shell †	151	C. F. ‡	20·5″	27 A4 C&H	5 0	1 14	800	2′L	...	...	28″	1170	Struck the middle plate 4′ 4·5″ from the right side and 5·5″ from the bottom, punched a hole in the plate 7·5″ × 6″; started three bolts in the lower row 1″ each, and narrow cracks extended from two of these bolt-holes to the bottom of the plate; one bolt in the top row of the lower plate was also slightly started. The plate was driven in below the hole ⅜ of an inch for a length of 12″. At the top of the target three of the filling-in pieces were blown out. The damage on the inside was as follows, viz.—a large irregular hole, inner diameter 10″; skin of ship bent out, with ragged rent, sticking out 10″; general bulge, distributed over a surface of 3′ 5″ × 3′ 5″. The shell evidently burst between the front plate and the skin, *i.e.*, in the wooden backing; the base and some pieces of the shell blown out in front of the target. Injury by fragments of the burst shell or splinters in the chamber (or interior of the target) not serious. A vertical rib was broken right through, and bent back. One of the bolt-heads broken off was 4′5″ from point struck.

The shell broke into fourteen large and nine small pieces; the following fragments of iron were picked up inside the target, viz.—eight large and ten small bolt-heads, eight rivets, three pieces of angle iron, and eight pieces of plate, including one large piece punched out.

* Muzzle-loading rifled gun. † Homogeneous metal. ‡ Cylindrical flat-ended.

Number of round.	Nature of ordnance.	Projectile. Nature.	Projectile. Weight in lbs.	Projectile. Form.	Projectile. Length.	Charge in lbs.	Bursting charge of shells.	Elevation.	Range in yds.	Deflection.	Effects. Depth of indent in inches.	Effects. Diameter of indent in ins.	Length of cartridge.	Velocity at 780 yds.	Remarks.
							lbs. oz.	° ′							
2	120-pr *	shell †	151	C.F. ‡	20·5″	27 A_4 C&H	5 0	1 14	800	2′L	...	...	28″	1180	Struck the top plate 2′ from the right side and 7·5″ from the bottom, nearly in line with one of the ribs, punching out a piece of plate 7·75″ diameter; the hole was stopped up with splinters of the backing; three bolts in the lower row, one in the centre, and two in the upper row of this plate were started from ·75″ to 1″ (one of the bolts which had started in the lower row was at a distance of 4′5″ from the point of impact), and the plate had started out from the backing 1·25″ on the right side; at the top the front baulk of the timber backing was blown out for a length of 2′, and the skin was driven back ·875 of an inch for the same length. At the back a large irregular breakage of inner skin; a piece of shell sticking in the hole shutting out daylight till removed. Inner diameter of hole about 10″; wood backing closed up considerably on path of shot; one rib broken and driven out, together with rent skin, about 1′; general bulge over a surface of 4′×4′. The shell exploded further forward this time, blackening the side of chamber and roof (corresponding to "upper deck") with bursting charge, and had evidently been diverted by striking in the line of the rib. Many (46) pieces of shell and inner skin of ship scattered about the interior. One piece of the former sticking in "upper deck," fragments had struck in every direction, in this instance, as far laterally as they could go (about 5′ 6″). The butt of the shell remained in the hole and was taken out from the front. The shell broke into thirteen large and six small pieces; fragments picked up inside:—six large and six small bolt-heads, seven rivets, three washers, and five pieces of plate and skin, including the large piece punched out.
3	”	H. C. §	130	”	17·″	”	...	1 5	”	nil.	2·3	7·	”	1227	Struck the centre plate 5′ from the right side and 6″ from the top, partly on a bolt, making an indent of 2·3″, and forcing in the plate at the top side for a length of 5′, to a depth of 3″ at the deepest point; a crack 11″ long extended from the top of the plate through a bolt-hole at a point 1′ 2″ from impact, also a crack 8″ long from the top of the plate, through a bolt-hole, at a distance of 1′ 4″ from impact; the plate buckled ·6″ at the right side; the shot broke up. At the back:—one vertical rib broken and one angle iron cracked. Six bolt and rivet heads broken off, at distances from point struck varying from 6″ to 4′. The shell broke into seven large pieces and a great many very small ones; fragments:—three large and three small bolt-heads, one rivet, two pieces of skin, and one piece of rib.

§ Hollow cast-iron shot.

Number of round.	Nature of ordnance.	Projectile.				Charge in lbs.	Bursting charge of shells.	Elevation.	Range in yds.	Deflection.	Effects.		Length of Cartridge.	Velocity at 780 yds.	Remarks.
		Nature.	Weight in lbs.	Form.	Length.						Depth of indent in inches.	Diameter of indent in ins.			
							lbs. oz.	° ′							
4	120-pr *	shell †	130	C.F. ‡	17·″	27 A_4 C&H	3 8	1 5	800	nil	...	...	28″	1245	Struck the centre plate and punched a hole 8″×7·5″; the hole was stopped up with portions of plate and splinters of wood backing. No damage at top of the target; at the back a large irregular hole 14″ in diameter, skin forced out 9″ to rear. The whole shell apparently, front and base, passed through in fragments, and apparently burst just as it broke the skin, as the hole itself was scarcely charred, and the "upper deck," above where the shell entered the ship's side, was blackened with powder. The shell broke into nine large and ten small pieces; fragments:—two large and ten small bolt-heads, seven rivets, five pieces of skin, a large piece of the plate punched out (broken in half), and a great many small pieces of plate.
5	,,	S.S §	129·5	,,	14·″	,,	...	1 3	,,	,,	...	...	,,	1204	Struck the middle plate near round No. 1, penetrated the target, making a clean hole 8″×8·3″ in the plate; the hole filled with broken pieces of plate; at the back the shot had penetrated close to the hole made by round No. 1, and the skin was now broken away for a space of 1′4″×1′5″; two former broken ribs driven out and bent back at considerable angle; and fibres of wooden backing and skin protruding 1′5″. Shot set up 2″. The following fragments of iron were picked up inside the target, viz.—one large and three small bolt-heads, three rivets, three pieces of skin, one washer and twenty-four pieces of plate, including a large piece punched out.
6	70-pr.	shell †	81	,,	19·″	13	3 12	1 7	600	nil	...	...	9″	Vel. at 580 yds. 1107	Struck the upper plate 13″ from the top and 3′ from the side; made a hole 6″×5·5″ and burst in the backing; a crack extended from the top of the hole to the top of the plate; one through bolt in the top row broken; at the top, the front baulks of the wood backing were blown out for a length of 1′, and a depth of 13″ from the top, and the rear baulks were blown out for a length of 5′ and a depth of 10″. The lower half of the shell and the piece of plate punched out were resting against the skin which was not penetrated; on the inside only one bolt-head broken off. The shell broke into ten pieces.
7	,,	,,	,,	,,	,,	,,	,,	,,	,,	,,	...	6·	,,	1104	Struck the target at the junction of the lower and centre plates; burst outside the target, punching a hole in the plate 4·35″ deep; two bolts, one on each side of the hole, started ·5″; a crack extended from a bolt-hole in the centre plate to the bottom of the plate, also a crack 6″ long parallel to the circumference of the hole, and 1·5″ below it. No damage visible on the inside of the target. The shell broke into two pieces.

* Muzzle-loading rifled gun. † Homogeneous metal.

‡ Cylindrical flat-ended. § Solid shot, homogeneous metal.

Number of round.	Nature of ordnance.	Projectile. Nature.	Projectile. Weight in lbs.	Projectile. Form.	Projectile. Length.	Charge in lbs.	Bursting charge of shells.	Elevation.	Range in yds.	Deflection.	Effects. Depth of indent in inches.	Effects. Diameter of indent in ins.	Length of cartridge.	Velocity at 580 yds.	Remarks.
							lbs. oz.								
8	70-pr.	shell †	72·5	C. F. ‡	16·"	13	2 10	1°	600	nil.	...	...	9"	1148	Struck the top plate 5" from the side and 6'5" from the bottom, and burst in the backing, which it penetrated to a depth of 11"; a large part of the shell remained in the rear baulk of the backing; a length of 3' of the front baulks very much damaged, 1' of it being blown out for a depth of 2' from the top, and 3" in thickness of the remaining 2' blown out for the same depth; the rear baulk was forced up 3" for a length of 2'6"; two bolts in the lower row started respectively 1" and ·5"; a crack from a bolt-hole to the bottom of the plate at 10" from the point of impact, also a crack 2" long immediately under the hole made by round No. 5; plate started out 1·25" on the right side, being now 2·5" from the backing; the butt of the shell was picked up 190 yds. in front of the target. No damage visible on the inside. The shell broke into fifteen pieces; fragments:—two pieces of plate (one punched out).
9	,,	,,	69·14	,,	,,	,,	Blind	59'	,,	,,	1·55	6·	...	1146	Struck the centre plate 6" from the top and 2' 8·5" from the right side; the top of the plate driven in 4" for a length of ·8"; a crack 8" long extended from the top of the plate through a bolt-hole; no damage visible inside. The shot broke into seven large pieces and twenty-four small.
10	12-pr‖	s. s¶	12·	,,	7·5"	1¾	...	5'	200	,,	·85	...	...	...	Fired at 2·5" plates (unbacked) at an angle of 45°. Plate starred at the rear, with three narrow cracks about 1" long; the shot broke up.
11	,,	,,	,,	,,	,,	,,	...	8'	,,	...	·5	...	...	...	No damage at the rear; the shot broke up.
12	,,	shell †	12·4	,,	8¾"	,,	Blind	9'	...	...	...	...	...	...	Struck the target 2·5" from the side, where the plate was supported on a framework of wood 8" thick; broke a hole in the plate and remained in it, projecting 7·5" on its upper and 4" on its under side, the timber baulk was smashed through for a length of 2'. The shell set up ·2".
13	,,	s.s.§	12·1	,,	7·1"	,,	,,	8'	...	...	...	...	...	...	Struck the plate 1' 5" from the side, and made a hole measuring 5·3" × 3·3" in front, and 7·5" × 8" in rear; the shot bounded back, and was picked up 25 yds. in front of the target. Set up ·2".
14	,,	,,	12·2	,,	,,	,,	,,	,,	...	...	...	...	...	...	Struck near the last round, and made a hole 4·9" × 3·1", and at the back the fracture had joined into that of last round, the hole now measuring 12" × 6·5"; the shot penetrated, and fell at the foot of the target, and was set up ·1".

‖ Breech-loading rifled gun. ¶ Solid shot, *cast-iron*.

September 8th.

The following experiments were to try the value of millboard as a backing to armour-plates :—

A piece of millboard 1' 3" × 1' 8·5" × 8" was secured in rear of an iron plate ·9" thick, the millboard resting against a 2½" plate backed by granite.

The gun used was a 6-pr. Armstrong rifled gun, with solid cast-iron shot and service charge, at 50 yds. range.

No. 1 round.—Struck the ·9″ plate at a spot above where it was backed by the millboard, made a clean hole 2·9″ diameter through the plate, and the shot broke up.

No. 2 round.—Struck the plate where backed; shot penetrated 3·9″ and remained in the hole unbroken. The millboard was slightly forced out at the side, owing to its small area.

No. 3 round.—Hit the plate at a spot 1″ below the top of the millboard; two inches of the rear of the shot broke off, the remainder remained in the hole, having penetrated 2·5″ into the millboard.

[A piece of teak 7·9″ thick was now put in rear of the ·9″ plate, just above the millboard, and resting against the $2\frac{1}{2}$″ plate and granite backing.
The 6-pr. Armstrong gun was used at the same range.]

No. 4 round.—The shot struck fair on the plate and wood, passed clean through both and remained whole in the wood, which was split in half. The shot penetrated to the $2\frac{1}{2}$″ plate.

The penetration into the millboard of a flat-fronted shot weighing $5\frac{1}{2}$ oz., fired from a wall-piece at 25 yds., with a charge of 10-drs., was 2·76″.

November 14th.

A block of millboard,* measuring 4′·75″ × 3′ 1·5″ × 1′ 2·5″ and weighing 6 cwt. $12\frac{1}{2}$ lbs., was tested in comparison with teak of the same *weight*, and measuring 4′·75″ × 3′ 1·25″ × 1′ 2″; each block was faced with a 1-in. iron plate, the whole being secured at the sides by means of clamps, to avoid through bolting.

The guns used were :—

One 6-pr. Armstrong gun, at 50 yds.
„ 12-pr. „ „ at 100 yds.

No. 1 round.—6-pr. solid shot at millboard. Struck 1′ 4″ from the top, and 1′ 6″ from the side; penetrated 3″ into the millboard, the shot remaining unbroken. The plate buckled ·95″ over a space measuring 17″ × 6″.

No. 2 round.—6-pr. solid shot at teak. Struck 1′ 3″ from the top, shot penetrated completely and broke up; the baulk of timber on which it struck was cracked through its thickness; very slight buckle of plate.

No. 3 round.—12-pr. solid shot at millboard. Struck the plate 1′ 2″ from the top, and penetrated to a depth of 1′ 7″, being 3″ into some wood in rear; left a clean hole through the millboard of 3·1″.

No. 4 round.—12-pr. solid shot at teak. Struck at 1′ 3″ from the top of the plate; made a hole 3·3″ diameter, and penetrated the wood, which was split through its thickness at the top; the hole closed up.

No. 5 round.—6-pr. solid shot at millboard. Struck at 6·5″ from the top, and penetrated the millboard to a depth of 2·65″, the fore part of the shot remained in the hole, the remainder being broken off. The plate buckled ·9″ for a space of 14″ × 12″.

No. 6 round.—6-pr. solid shot at teak. Struck at 1′ from the top, and penetrated 6″ into the teak, the wood was split through, as in previous rounds; very slight buckling of plate. The shot did not break up.

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* This block of millboard was supplied by Mr Morris, of Glasgow, on his own proposal, but was not at all suited for the purpose intended, consisting merely of sheets of brown paper laid together and bound by hoops of iron, and when these latter were removed, the sheets of paper were found to be quite disconnected.

REPORT,

OF THE

MARCH OF A HALF-BATTERY ("G" BATTERY, 4TH BRIGADE), ROYAL ARTILLERY, FROM SAINT JOHN, NEW BRUNSWICK, TO THE TERMINUS OF THE GRAND TRUNK RAILWAY, AT RIVIÈRE-DU-LOUP ON THE SAINT LAWRENCE. FEB. 6TH TO 16TH, 1862.

BY LIEUT. F. M. SMITH, R.A.

IN the commencement of 1862, three Batteries of Field Artillery were sent from St John, New Brunswick, to Rivière-du-loup, on the Saint Lawrence. Two of these, "E" and "G" Batteries of the 4th Brigade were sent the whole way across country, by half-batteries, without any difficulty; and the following particulars relative to the transport of a half-battery have been collected with a view of showing how it was accomplished. The third battery, "F" of the same brigade, was sent from St John to St Andrews by sea, thence by rail to Woodstock, and thence across country to Rivière-du-loup.

Embarcation of "G" Battery.

"G" Battery, 4th Brigade, R.A., under the command of Major D. E. Hoste, C.B., embarked at Liverpool on board the "Hibernian" on the 1st of January, 1862. The strength of the battery was six officers, and 252 non-commissioned officers and men. The guns (12-pr. Armstrong), carriages, and equipment were supplied new, from the Royal Arsenal, Woolwich, and along with the battery were sent thirty sleighs, which had been constructed in the Arsenal, intended for the transport of the battery in British North America.

Before shipping the guns, the tangent-rings and sights, the handles of the breech screws, and the elevating screws were removed; and a piece of soft wood fixed over the dispart and trunnion sights. The wheels and shafts were then taken off all the carriages, and the battery packed on board ship.

Landing of "G" Battery at St John, New Brunswick.

The battery landed at St John, New Brunswick, on the 20th of January, 1862. The guns and equipment were landed the next day, placed on the sleds used in the town for heavy loads of any description, and drawn up to the permanent barracks. Here the wheels and shafts were put on and the battery parked in the gun shed. The men were lodged in the Custom-house; some of the large rooms in it having being converted into a temporary barrack. No day was fixed for the march of the battery up country for some time after landing, in consequence of the large bodies of troops waiting at St John to be sent forward.

English sleighs condemned.

Soon after landing, a board of officers assembled by order of Major-General Rumley, commanding at St John, to examine and report on the sleighs which had been sent from England, for the transport of the battery. These sleighs had been turned out at very short notice, by the Carriage Department of the Royal Arsenal. The board proceeded to examine them, and took the opinions of several persons well acquainted with the transport in the province, and came to the conclusion that the sleighs were not only of no use, but that to employ them would be to destroy any road on which they were used. The principal objections against them were,—

Theirfaults.

The shortness of bearing, and thickness of the "runners;" their height; the bad position of the draught; and the fact that the "runners" were constructed of a single piece, leaving no escape for the snow which might be forced up between them.

The experience acquired on the march proved that these objections were very well founded; for in the first place, no team of horses could have dragged them, with their clumsy "runners" shod with rough unpolished iron, for any distance without soon becoming knocked up; and had they been, with great difficulty taken any distance into the interior of New Brunswick, they must have capsized continually, from the nature of the roads over which they had to travel.

These sleighs having been condemned, it was proposed by the Quarter-Master-General's department at St John, to call for tenders for the construction of new sleighs for the transport of the battery, but this plan was abandoned.

The next plan proposed was to issue advertisements for transport of the battery from one station to another along the line of march, it being intended that the guns and equipment should be transhipped from one set of sleighs to the other; but Lieut.-Colonel Turner, C.B., commanding 4th Brigade, wrote a letter (dated January 30th), intimating that he considered such a plan would be highly injurious to the guns, carriages, and equipment, so this plan was also abandoned.

Thirty-six country sleds hired for the conveyance of the battery.

Finally an arrangement was made with three contractors to convey the whole battery from St John to the Rivière-du-loup, on thirty-six of the common farm sleds of the country; and in two days the whole number required were ready.

These sleds were for the guns and equipment alone, the men being conveyed by separate contractors.

Two of these sleds packed by "G" Battery for approval.

As soon as the plan was decided on, two of the sleds were packed by "G" Battery, one with a gun, pair of wheels, and pair of shafts; the other with limber, boxes, &c., and submitted for inspection to Major-General Rumley, who approved of the plan of packing proposed.

Landing and forwarding of "E" Battery, 4th Brigade.

"E" Battery of the 4th Brigade, R.A., commanded by Captain G. H. Vesey, having landed at St John on the 26th January, was put in order to proceed up country before "G" Battery. Thirty-six sleds for the conveyance of this battery were ready on the 1st of February. The right and left half-batteries were packed on the 2nd and 3rd February, respectively, on the plan proposed by "G" Battery, and started for Rivière-du-loup on the 3rd and 4th February, 1862.

Packing of "G" Battery.

On the 4th of the same month, 18 sleds were ready for the "left-half" of "G" Battery, and the half-battery including harness and stores of every kind, was packed on the sleds in a day. In like manner the right-half-battery was packed on the 5th; the "left-half" started on the 6th, the right following the day after.

Description of the sleds used.

Before attempting to describe the way the various carriages were packed on the sleds, it will be necessary to give some description of the nature and construction of the sleds furnished by the contractors.

They were the common sleds of the country such as are used for farm purposes or for heavy loads of any description, and are well adapted for the purpose for which they are used. They are drawn by a pair—or as it is called in the country—a "span" of horses, and can convey a load of nearly 2 tons in weight. They can be had in any numbers, so that as far as the mere *transport* of artillery is concerned, it appears very unnecessary to attempt to construct sleds in England, for use in New Brunswick or Canada. The inhabitants of these provinces are more likely to be able to furnish sleds such as will suit their own roads, and of which the draught will be easy, than any artificer, however skilled, can hope to do at home in England.

All of the same width to suit the roads.

These sleds vary in almost all their dimensions, except their *width*, which in New Brunswick never varies more than two or three inches. If a sled were constructed very much wider or narrower in the "runners" than usual, it is manifest that the "runners" would not run in the hardened snow track on each side of the central of the roads, but in the soft snow inside or outside it, increasing thus the weight of the draught immensely. The general width of the sleds used on the New Brunswick roads is 4 ft. 2 in. to 4 ft. 4 in. In Canada where the government can afford to send the snow-plough and roller over the roads, a greater latitude can be allowed.

In the contracts entered into at St John, no regulations whatever, as to dimensions were specified, only the "common bench sleds" of the country were called for. Hence many of the sleds varied in dimensions very considerably, but all with the exception of one, carried their loads through to Rivière-du-loup. This one was about 4″ further apart in the "runners" than all the others; and although the "shoes" of the "runners" were polished by long wear as smooth as possible, the team drawing it was knocked up and unable to go on, at the end of the third day's march, and a fresh sled had to be provided and the load shifted.

Parts of the common bench sleds.

The principal parts of the "common bench sled" are,—

The "runners."

(1) The "runners," generally constructed of the black birch, and shod with iron or steel. In wild districts where no iron or steel is to be had, the runners are sometimes constructed of beech alone without any shoes, and the wood of that tree being so smooth and hard, makes a tolerable substitute for iron-shod runners. The runners average in length eleven feet, and are generally five inches wide and about two thick. It is of great consequence that they be constructed of good, sound timber, as they are liable to be split sometimes, in "slews" on the road, as will be afterwards explained. Only those of the more finished sleds

are shod with steel, iron being the commoner material. The steel is much more expensive, but it has the great advantages of lasting much longer, and not "hanging" so much as iron when it comes in contact with a stone.

It is indispensably necessary that the shoes of the runners, whether they be of iron or steel be *polished* before starting on a journey: this can readily be done by means of a piece of wood and some sand. If not polished before starting the rough metal takes a long time to wear smooth, and the draught is much heavier.

The "benches."

(2) The "benches," are four pieces which connect the runners together. They are arch-shaped, and are made of a single piece, Fig. 1. They

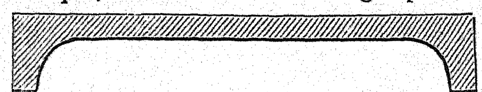


Fig. 1.

are generally 9 in. in height, and 4 in. thick. Thus, the bed of the sleigh which rests on them is not more than 14 in. from the ground, offering a favourable contrast to those of the English made sleds which were nearly three times the distance.

Method of fastening the benches to the "runners."

There are two ways of fastening these benches to the runners, viz. by wooden pins, or by iron bolts. Both systems have their advantages. The pins, whether of wood or of iron are inserted into the runners, but do not pass *through* the benches; they fit into channels cut in their sides for them

Fig. 2 shows the ends of the two benches connected together by

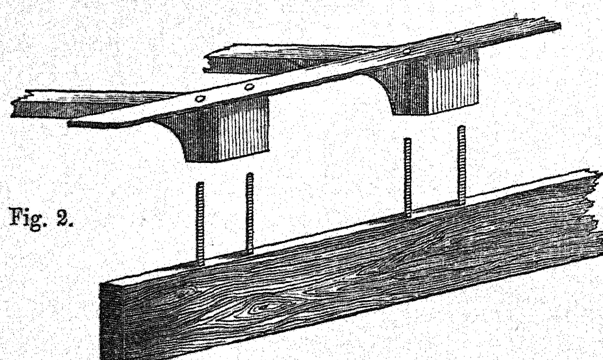


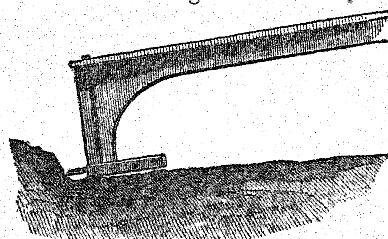
Fig. 2.

Wooden pins compared with iron pins.

the "*rave*," (see p. 183), and also the general arrangement of the pins. If wooden pins are used, a wedge is driven into a split in the top of them, and the slight expansion caused by this, is all that there is to prevent the bed of the sleigh being lifted off the runners; if iron pins are used there is a nut on the top, which being screwed down keeps everything in its place. At first sight it may appear that the iron pins are better than the wood, but there is much to be said on both sides; and the wooden ones seem generally preferred for this reason, that if the sled be subjected to any very severe "slew," (*i.e.* if one side of the road shelves down to one side, and the sled sways suddenly down), the pins will break and the runners

be uninjured, in which case the pins can be replaced in a very short space of time. But if iron pins are used, a severe slew will split the runners, rendering the sled totally unserviceable. Figs. 3 and 4 are imaginary representations of the effect of a slew upon wooden and iron

Fig. 3.



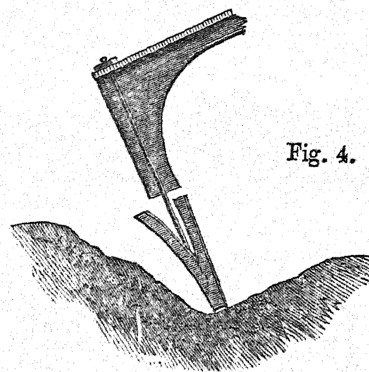


Fig. 4.

pins. Fig. 3 showing the effect on a sled with wooden pins; the pins having broken off, and the runners being detached and lying under the sled; Fig. 4 exhibiting the way in which the runner gets split when iron pins are employed.

An instance of fracture of the wooden pins of a sled took place on the march, exactly as represented in Fig. 4; the pins were replaced and the sled ready to continue its journey in about 20 minutes.

Frame sleds.

These "benches" are only employed for sleds intended to do slow, heavy, work; other sleds generally have "frames" instead; that is to say, they have a "frame" constructed of several pieces mortised together, instead of a single solid bench. Sleds so fitted are called "frame-sleds," and are more durable and more expensive than common bench sleds. A common bench sled shod with iron costs about £5 sterling, in New Brunswick; a frame-sled, shod with iron about £10; and a frame-sled shod with steel about £20.

The "raves."

(3) The "raves" are two long pieces, extending the whole length of the sled, connecting the benches together, and between which the bed or floor of the sled, consisting of planks is placed.

The "pole" or "tongue."

(4) The tongue or pole.

The "sky-piece."

(5) The sky-piece, is a curved piece of wood connecting the front end of the runners together. Fig. 5, p. 184 shows the tongue, sky-piece, and method of attaching the draught.

The draught.

Weight such sleds can carry.

Sleds such as above described, are supposed to be able to carry loads of 2 tons weight, and are drawn by a pair of horses.

The battery loads all reduced to 1 ton.

As the journey to be performed by the half-battery was to be a very long one, an agreement was made with the contractors who furnished the sleds, that none of the battery loads was to exceed 1 ton in weight; and it was calculated that eighteen sleds could convey the half-battery, with harness, equipment, and everything complete.

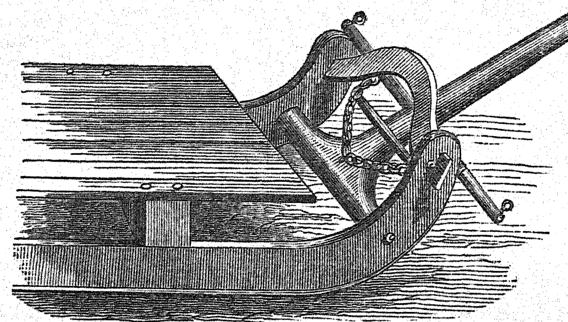


Fig. 5.

Before the packing of the battery was commenced, a few lessons in simple lashing were given to the non-commissioned officers.

Stores used in packing the battery.

For the packing of the battery a large supply of the following stores was demanded and supplied, viz.,

Timber 4″.
Rope, white, $1\frac{1}{2}$″ and 1″.
Rope, tarred, $\frac{3}{4}$″.

The tarred rope was found to be so stiff from the intense cold, that it was almost useless.

Previous to commencing the packing a certain amount of arrangement had to be made, in order that none of the loads should exceed 1 ton in weight. Consequently the load that each sled had to carry was arranged beforehand, so that the whole packing, was done in a single day without any trouble or confusion.

List of the loads of the eighteen sleds for a half-battery.

The following is a list of the loads of the eighteen sleds :—

No. 1. Gun on carriage (wheels removed), pair of shafts, drag-ropes, &c.

No. 2. Gun on carriage, pair of shafts, tents, &c.

No. 3. Gun on carriage, pair of shafts, drag-ropes, small stores, &c.

No. 4. One limber body, and two limber boxes, pair of shafts, 2 pair of wheels.

No. 5. One limber body, four limber boxes, pair of wheels, wheelers' tools.

No. 6. One limber body, four limber boxes, pair of wheels.

No. 7. Wagon body with four boxes, pair of wheels, spare perch.

No. 8. Wagon body with four boxes, pair of wheels.

No. 9. Wagon body with four boxes, two limber boxes, pair of wheels.

No. 10. One limber body and two boxes; one limber body, three wheels.

No. 11. One limber body and boxes; one limber body, two pair of wheels.

No. 12. Seven wheels, three pair of shafts.

No. 13. Store limber wagon body, pair of wheels, tents, &c.
No. 14. Limber body of store wagon, and box, two pair of wheels.
No. 15. Six vats equipment, tents, &c.
No. 16. Ten boxes equipment, arm chest, &c.
No. 17. Four boxes do do.
No. 18. Eight boxes do do.

It will be observed from this list that more than its proper compliment was sent with the left-half-battery, the object of this being to make up loads of proper weight.

Method of packing and lashing. The method of packing and lashing the various loads was so simple that it requires but little explanation. Each of the sleds intended for a gun, limber body, or wagon body, was fitted with two four-inch pieces of timber laid along the whole length just inside the raves, and secured to the sled with a few small nails driven in at the ends. In these pieces mortises about two inches deep were cut to receive the axletree beds; these mortises being if possible directly over one of the benches (Fig. 6) of the sled. **Preparation of sleds for gun or wagon bodies.** The sleds intended for the three guns, had an additional piece in front, supported by the two others, for the trail of the guns to rest on. This cross piece was spiked down to the long pieces, and had two cleats nailed on to receive the trail, and prevent it moving laterally. The object of this arrangement was to distribute the weight evenly over the sled, and prevent too great a pressure at any particular point.

Packing the wagon bodies. The same arrangement was made for the wagon bodies; for the limber bodies, two being carried on one sled, a double set of mortises had to be cut. The object of cutting the mortises directly over the benches, was to enable a single lashing to be passed round the axletree arms and the benches immediately under them.

Had the mortises, and consequently the axletree arms, not been directly over the benches, a *double* lashing, one forwards and another backwards would have been necessary to prevent the carriage from moving backwards or forwards. But, in the arrangement made, only one lashing was required.

When the sleds were prepared in the manner described, they were packed in a very short space of time, the wheelers of the battery making fresh sleds ready, while the others were being packed. The guns were run over the sleds from the rear, trail first; the wheels were then taken off, and the axletree bed and trail lowered into the mortises prepared for them. The tangent ring and sight, handle of breech screw, and elevating screw were removed, and packed in a box placed under the muzzle; a small piece of lashing was passed round the breech and the trail, and then hay bands were twisted all round the gun to protect it from the weather. **Lashings required for the guns.** The only lashings required to keep the gun securely in its place on the sled were four; one for each axletree arm, and one for each trail handle. The benches of the sled being the only part to which a lashing could be fastened, the axletree arms were lashed to the bench immediately underneath them (see Fig. 7), and the trail handles, projecting a good deal in front,

were lashed to the front benches. This latter lashing was so very oblique, as to be of little use in preventing the trail pitching a little when going over very rough roads.

Lashings of the wagon bodies. The wagon bodies were packed in the same way as the guns, and the perches not projecting so far in front were more securely lashed down.

Lashings of the limber bodies. The limber bodies were secured to the sleds in the same way, by lashings round the axletree arms; and the splinter bars rested on a cross piece, the whole being lashed down to the sled.

Store-limber wagon; method of packing. The store limber wagon was packed in the same way, perch to the front.

Timber to protect the axletree arms. When the sleds were packed, a stout piece of 4″ timber was passed across underneath the trails of each of the guns and under the wagon bodies, projecting as far as the ends of the axletree arms, and fastened down by spikes to the two longitudinal pieces. These were intended to protect the axletree arms. This arrangement was suggested by Lieut.-Colonel Turner, C.B.

Packing of the sleds for the boxes and vats. The four sleds which carried boxes and vats, and the one on which were packed 7 wheels and 3 pair of shafts required no preparation, but the lashing of these loads was a more difficult matter. After they were lashed, two or more packing sticks, termed "swifters" in this country, were twisted into the ropes, and whenever any of the lashing stretched (which the white rope did very considerably), it was easily tightened up again.

Hay bands employed to prevent chafing. When any two parts of different carriages touched one another, when packed, or when wheels or shafts were packed on the top of boxes, &c., hay bands were twisted round them to prevent chafing or damage.

No parts of the carriage taken to pieces in this method of packing. It will be observed that in the above method of packing, nothing was taken to pieces; nothing was removed from its place but the wheels and some of the limber-boxes, in order to distribute the weights more evenly. Consequently the whole of the guns and carriages could be put together in a very much shorter space of time than was taken in packing them, as experience proved.

The half-battery was packed on the 4th, and put in order to start on the 6th of February. For the detail of the party, see Appendix, No. VII. p. 206.

Preparations made for the march by the Qr.-Mr.-Gen. Depart. at St John. Before giving an account of the march it will be necessary to give some account of the preparations that had been made, and the various orders that had been issued regarding it. So well was everything arranged along the whole line of march, by the Quarter-Master-General's Department at St John, that little had to be done by officers commanding detachments. There were officers of the Medical and Commissariat Departments at each station on the road, and all arrangements relative to the lodging and rationing of the troops, were so complete that no trouble or confusion was ever experienced at the end of a day's march.

Warm clothing for the men. The men were well protected against the cold, on the journey. The extra articles of clothing which they wore, were, a chamois leather waistcoat, seal skin cap and mits, and a comforter; and they each

were served out with a pair of moccasins for the march. They wore their cloaks, and every man had two blankets and a waterproof sheet. They generally wore one blanket tied over their heads as a sort of hood, and the waterproof sheet outside it to keep the wind out. The other blanket they wrapped round their legs, and with these and the buffalo robes in the sleighs, they were generally quite warm and comfortable.

Sleighs for the conveyance of the men.

The sleighs in which the men were conveyed were, as far as framework and runners are concerned, identical with those described for the transport of the guns, &c. They were fitted however with four rough sides, across the top of which were nailed seats for 8 men, 3 rows of 3 including the driver. They were not supplied by the same contractors as the gun sleds, and many of them did not make more than two or three days' journey, returning after having done so, and their places being taken by others. This was a source of inconvenience for two reasons; first, the drivers of these sleighs having only short journeys to make, of two or three days, were always pressing forward, and endeavouring to get ahead of the gun teams in order to secure the best stabling, thus destroying the order of march; and secondly, much time and trouble were required to make the new drivers acquainted with the various orders relative to the arrangement, &c. of the line of march.

Printed orders given to officers commanding detachments.

Three printed orders were given to each officer going up country in command of a party. They were issued by the Quarter-Master General's Department at Saint John. Copies of two of them, the first, "Memoranda for the guidance of Officers," the second a "List of half-way halting places," will be found in the Appendix, Nos. II. and III., pp. 200, 201, and an abstract of the third, which relates to the rationing of the troops. A perusal of these will show the arrangements made, better than any description.

Arrangement of the line of march.

In addition to these, full directions were given as to the arrangement of the line of march; about which a few words must be said before going further.

The first day's march from St John was arranged as follows:—

The half-battery was subdivided into two halves, the one called the "Equipment Detail," and the other the "Movable Detail." The latter consisted of the greater part of the men, including a party of 2 officers and 61 men of the 63rd Regt. as escort, the three guns, and three sleds containing wheels, limbers, and shafts. The "Equipment Detail" contained the twelve other sleds, carrying the wagons, harness, vats, &c. &c., and three sleigh detachments, 24 men. This latter, being considered the heaviest and consequently the slowest part of the train, though in reality all the loads had been as nearly equalized as possible, was ordered to start an hour before the other in the following order:—

3 sleighs equipment.	5 sleighs equipment.
1 „ detachment, 8 men.	1 „ detachment, 8 men.
4 „ equipment.	1 „ baggage.
1 „ detachment, 8 men.	

The "Movable Detail" was ordered to follow an hour later in the following order:—

5 sleighs	detachment, 8 men each.	1 sleigh	gun.
1 „	gun.	1 „	limber, boxes, &c.
1 „	limber, boxes, shafts, &c.	4 „	detachment.
4 „	detachment.	1 „	men's baggage.
1 „	gun.	1 „	officers' do.
1 „	limber, boxes, &c.	1 „	officers.
4 „	detachment.		

In each of these parties there was a "head teamster" or "captain of the teamsters" appointed, who was to drive the leading team, and so regulate the pace; and strict orders were given to the other teamsters, that no halt either for watering or feeding was to be made without the "head teamsters" permission; and also that every sleigh was to keep the sleigh in front of it, and the one in rear of it, always within hail.

This arrangment faulty, and why.

This order of march did not answer well, as the gun sleds were quite as heavy as those in the equipment detail, consequently the movable detail did not move any quicker than the equipment detail, and the men were thus longer exposed to the cold and later in arriving at their destination than was necessary. The object of the arrangement was of course to have the guns and a portion of the ammunition always with the larger body of troops. But the American difficulty was adjusted before the half-battery started, and there was consequently little or no risk in sending it even close to the frontier. The order of march was therefore changed, by authority from St John, and for the last eight days of the march, all the gun, limber, wagon, and equipment sleds with three sleds detachments Royal Artillery, and three do. 63rd Regt. as escort, were sent on at least an hour, or an hour and a half before the larger body of men, which then followed at a much more rapid pace, thus saving the men much exposure. With this arrangement, both parties generally arrived together, the second party generally catching up the first, shortly before the end of the day's journey.

Change of order of march.

In the detail of the party it will be observed that one man of the Royal Engineers accompanied the party. He was sent up in order to join his company then at Fredericton.

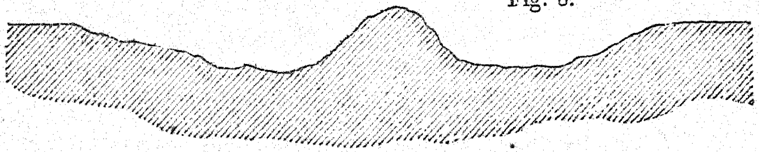
Character of the roads in New Brunswick.

Before attempting to describe the journey, a few words must be said on the roads of New Brunswick, and their character in winter. All the roads in this province are divided into great roads and bye roads. The former are those on which much regular traffic takes place, and they receive a greater amount of legislative aid than the bye roads. The great roads are kept in repair by the inhabitants of the various districts through which they pass, but in winter very little seems to be done to them. The road from St John to Little Falls, by which the troops marched, though the principal road in the province, was in a very bad state, and had many dangerous places in it, all of which seemed of old standing, and in one or two places only, had repairs been made.

In winter when all the traffic is carried on by sleighs, the road is simply a track, the breadth of a sleigh, worn, and beaten hard in the snow. There is only a single track, so when two sleighs pass each

other, one of them has to go off into the deep soft snow at the side of the beaten track. The track consists of a level surface on each side worn smooth by the sleigh runners, and as we previously stated all the sleighs used in the province have the runners the same distance apart; if not they would be unserviceable for long journeys, from the heaviness of the draught. The draught of the New Brunswick sleighs is almost always double; hence the snow in the centre of the road gets worn into two channels with a ridge of snow between them (see Fig. 8), which is an imaginary section of a New Brunswick road. The

Fig. 8.



consequence of this is, that when single draught is used, the shafts must be attached *not* in the centre of the sleigh, but to one side, in order to allow the horse to run in one of these channels.

Faults in the roads. The roads, &c., "cahôts" and "slews."

The principal obstacles or faults in these roads in winter, are two; viz. "cahôts" or pitches, and "slews." The former are deep holes running across the road, generally at the foot of a steep descent, and they become enlarged by every sleigh which passes over them. "Slews" are portions of the road, which shelve down on one side, and on which a sled sways down sideways, each one making the slew worse. Both these are dangerous for heavily loaded sleighs, the latter especially. A sleigh pitches into a cahôt with a heavy blow which shakes every timber in it; and when passing a slew, sways down sideways, being brought up at the bottom by a bank of frozen snow or ice, which is very likely to break the pins or split the runners as previously explained. (See page 183.)

Mode of mending cahôts.

The "cahôts" are mended by putting in alternate layers of young spruce boughs and well-rammed snow. Snow by itself would be of no use, for being softer than the beaten track, and having nothing to hold it, it would soon be hollowed out again.

Bridges in New Brunswick.

The bridges in New Brunswick are of inferior quality, as there are so many required, that no great amount of engineering seems to have been bestowed on any of them. The same want of supervision, visible in the state of the roads, is also to be seen in the case of the bridges. If one is carried away by a flood, unless the legislature is sitting at the time, it cannot be repaired till the next session. Many remains of broken bridges are seen along the road; but it must be remembered that there are such large quantities of timber, always at hand, that in the event of a bridge breaking down or being carried away, another could be constructed, in an emergency, in a very short space of time. Most of the bridges, indeed, are made of logs cut and squared on the spot; they are all constructed on the strut and tie principle.

The above remarks apply only to the roads of New Brunswick. In Canada, the roads are in very much better condition, as much more trouble is taken with them.

How the weather affects the roads in winter.

As a general rule, the harder the frost is, the heavier is the road; for in very cold weather, the snow becomes frozen and is in a state of powder, and the slightest breath of wind causes this to drift into the track. The sleigh runners drag very much in this, producing a peculiar creaking sort of noise, which cannot be mistaken. A hot sun, or better still, a slight fall of soft snow makes the roads much easier, and the sleighs then glide along without making any noise whatever.

Difficulty of making any observations on the march.

The difficulty of making any regular observation either of the nature of country or state of the roads was very great; for in the first place, everything was thickly covered with snow, sometimes of great depth, beds of rivers, ravines, &c. being completely snowed up, and leaving no mark of their situation; and in the second, the cold was generally so intense as quite to preclude the possibility of making any notes at the time, so that anything worthy of note had to be written down from memory at the end of a long day's march.

Halting places between St John and Rivière-du-loup.

The stages of the march between St John, New Brunswick, and Rivière-du-loup are the following:—

(1)—24 miles.		Petersville; a log hut in the parish of the same name.
(2)—38	„	Fredericton; the capital of the province, a town on the St John River.
(3)—30	„	Tilley's; a settlement on the St John river.
(4)—32	„	Woodstock; a town on the river.
(5)—23	„	Florenceville; a settlement on do.
(6)—26	„	Tobique.
(7)—24	„	Grand Falls.
(8)—36	„	Little Falls, all villages on the same river.
(9)—37	„	Fort Ingall, a blockhouse fort and settlement on Lake Temiscouata.
(10)—42	„	Rivière-du-loup; a town on the St Lawrence.

In all 312 miles, ten days' journey. The road is the post road, and is one of the best in the province.

Start of the party.

The party detailed, left St John at 7.30 and 8.30 a.m., on the 6th of February, 1862. The following were the officers who accompanied the party:—

Royal Artillery, 4th Brigade,—

Lieutenant F. M. Smith.
„ H. Anderson.
Asst.-Surg. W. R. Steuart, M.D.

63rd Regiment,—

Lieutenant F. Hulton.
Ensign J. Thacker.

The total number of sleds was 42, distributed as follows :—

Half-battery of Artillery	18	sleds.
Men	20	„
Baggage (officers and men)	3	„
Officers	1	„

Each officer was allowed only 100 lbs. weight of baggage. Weight of luggage allowed to officers.

First day.—*St John to Petersville, 24 miles.*

First day's march. The day was very fine and clear, but the temperature was very low, several degrees below zero when the party started. The road on leaving the town winds over a hilly country for about four miles in a north-westerly direction, till it reaches the "bay" or lake formed by the junction of the St John and Kenebecasis rivers. It comes on the bay about three miles above the mouth of the river, which runs into the harbour of St John between two lofty rocks spanned by a suspension bridge.

The bay being always frozen over in winter, and a road being made across it, marked by spruce boughs stuck in the snow, a considerable distance is saved by crossing it instead of going round by the suspension bridge. The road strikes the bay about the foot of Kenebecasis bay, which is a long stretch of water navigable by steamers for 20 miles, formed by the rivers of the same name. It first crosses this, and then the St John, making a total of 7½ miles on the ice. When the sleds got on to the ice and out of the shelter of the land, they became exposed to a keen breeze which was blowing, which made the cold to be severely felt.

The snow also drifted, making the road very heavy, so the gun and equipment sleds made very slow progress. The bay is surrounded by ranges of hills thickly covered with forest, so the scenery is very fine. Five miles after coming on the ice brought the party to a point called Brundage Point. This point is in King's County, on the left hand of the road, and lies opposite the foot of the "Long Reach" of the St John, up which the eye can travel for a great distance; and about two miles further on the road quits the ice, entering King's County. The shelter of the land as the party approached it was found to be very welcome, and the sun being then powerful, the weather was quite warm. The road after leaving the ice winds along the side of the river, having a range of wooded hills on the left, and about three miles further on passes the Douglas Arms inn, where the party halted for an hour. This inn is situated near the mouth of the Nerepis river, from which the whole road between Saint John and Fredericton takes its name, and is by road eighteen miles from St John. After leaving this, the scenery becomes magnificent; the hills become loftier and approach nearer to the road, till they overhang it in lofty cliffs and crags thickly covered with pine woods. For some distance the road winds through thickly wooded defiles, amongst which the "Eagle Heights"

must be noticed for their magnificent scenery. But soon the defiles open, and the road loses its wild character as it enters Welsford and Douglas valleys. A few miles more brought the party to its destination, the log huts at Petersville. There are here only two huts, one for the officers and another for the men, and a cook house. The men's hut could only accommodate 120 men, so forty men were sent on about half a mile further, to an inn on the road where accommodation was provided for them. Officers and men slept on beds of young spruce boughs, and as there were stoves in both the huts, did not suffer much from the cold.

At the end of this day's march, the Assistant-Quarter-Master-General at St John was informed by telegraph, of the safe arrival of the party. This was done (by order) every day. To the existence of the telegraph, along the whole line of march, must be attributed no small share of the success with which everything was carried out. If a detachment was detained at any place, by severe weather, it was telegraphed to all the halting places on the road, and all the detachments were delayed, till the stoppage was removed. In this way any overcrowding at any one station was prevented. Besides this the telegraph was of the greatest use on many occasions.

Second day's march.

SECOND DAY.—*Petersville to Fredericton*, 38 *miles*.

The two parties started at 7 and 8 a.m., the weather being a little overcast and milder, but the roads were still very heavy from the quantity of drift. The first ten miles of this day's journey was over a very hilly country; on each side of the road for about one mile, the land is cleared and occupied by settlers. The greater part of these clearings, however, are only "first clearings;" that is to say, the trees have been felled and burnt, the stumps being left in the ground, and a crop got off the land. The second clearing does not generally take place till eight years after the first, when the stumps being rotton they are easily removed. The houses occupied by the settlers are log huts, formed of rough logs placed one above another, the ends crossing.

Behind the cleared land all appears to be forest, and forest which indicates poor land, viz. "soft wood," that is to say, evergreen; viz. firs, spruce, pine, hacmatac or larch, and cedar. Good land is always indicated by the presence of "hard wood," as it is called; that is to say, trees which drop their leaves in autumn, viz. rock and white maple, oak, elm, ash and hazel. This appears to be caused by the nutriment afforded to the soil by the fallen leaves.

After the first ten miles the clearings become less frequent, till at last the road passes through the forest, which is here all soft wood. About twenty miles from Petersville there are a few more clearings, and at twenty-two, a miserable inn called "Perry's" from the name of the proprietor. Here the mid-day halt was made. The weather was now much overcast, and a slight fall of snow commenced which lasted the remainder of the day. After leaving the halting place, the character of the road continued much the same,—long stretches of woods with occasional clearings, till it strikes the St John river, at the village of Oromocto, situated at the mouth of the river of the same name, about eleven miles

from Fredericton. The Oromocto is one of the principal tributaries of the St John river; it is a deep river navigable for twenty miles, and some ship building is carried on in the village. It is crossed by a rough wooden bridge.

The land along the bank of the St John between this point and Fredericton is of excellent quality, and there are several large islands in the river which produce very large crops of hay, from being often overflooded. The character of the trees is totally different here also; instead of soft wood so common along the road, they are principally large elms, oaks, and other forest trees. About four miles from Fredericton, the road passes into York Country. Of this county, Fredericton is the capital, as it is of the whole province. It is a pretty little town lying on the bank of the river, and has barracks for 1000 men, besides an artillery barrack. The party did not arrive till nearly 7 p.m: the men were lodged in the barracks, and the officers billeted in a hotel.

The health and spirits of the men were good, and they seemed to enjoy the novelty of the journey. The order marked No. V. see App., p. 204, was handed to the officer commanding the party on arrival.

Third day's march.

THIRD DAY.—*Saturday, Feb.* 8. *Fredericton to Tilley's*, 30 *miles*.

The weather on starting was clear and cold, and continued so the whole day. The road winds along the southern bank of the St John river the whole way, never distant from it more than three-quarters of a mile, and lies in the county of York. A few words must be said on the St John river, though it would be quite out of place attempting to give a regular description of it. This noble river which rises in the State of Maine, and forms the boundary between that State and New Brunswick, in one part of its course, and which runs into the sea at St John, is navigable for steamers from its mouth up to Grand Falls 200 miles above it. The navigation is of course interrupted there, but it is carried on above the Falls for a long distance. In summer, eight to ten steamers ply between Saint John and Fredericton, doing the journey upwards in about eleven hours, and downwards in a much shorter space of time. The scenery on its banks is of great beauty, and the road to Rivière-du-loup follows the bank the whole way from Fredericton to Little Falls, six days' journey.

On leaving Fredericton, the road winds along the side of a lovely valley, the river lying at the bottom, and the sloping sides of the hills being cleared and cultivated up to the top. Soon the road becomes more hilly, and is crossed by numerous small streams, running through deep ravines, spanned by bridges of rough timber. At one point about ten miles from Fredericton, the St John winds round a steep rocky point, with a steep descent in the road. The mid-day halt was made at a tavern in Kingsclear parish, about sixteen miles from Fredericton. During the latter half of the journey the road was not so hilly, but was very full of cahôts and bad places. The party arrived at *Tilley's*, a poor inn kept by a man of the name, about half-past six p.m. The inn lies on the slope of a hill, distant about one mile from the river, and there are some few houses round it. The whole of the Artillery were billeted in

the inn, their beds, being as was the case at every halting place, young spruce boughs laid on the floor. The detachment of the 63rd regiment were lodged in a school house, and building in rear, about 200 yds. distant from the inn.

This day's march completely knocked up one of the teams of the equipment sleds. On examining the sled it was found that the runners were four inches further apart than those of the others, and this circumstance alone made the draught so heavy, that a new sled and team had to be procured. This is a clear proof that to have attempted the journey with the sleds made in England, would have resulted in failure. The roads were very heavy during the day's journey.

Fourth day's march.

FOURTH DAY.—*Sunday, Feb.* 9. *Tilley's to Woodstock*, 32 *miles*.

The weather was lovely beyond description, bright and clear, without a cloud in the sky, but the cold was intense and the roads still very heavy. The remarks on the road yesterday apply almost equally well to this day's march. The road winds along the bank of the river the whole way, passing along the sides of gently sloping cultivated hills, or steep banks covered with trees and intersected by numbers of small streams and hollows. Some of the descents in the road were very steep, and the slews were so numerous, as to endanger the poles of the sleds; for when a pole slews, the lowest side generally sticks in the snow, and thus throws a tranverse strain on the pole. The whole of the road between Fredericton and Woodstock is a very costly one to keep in repair, owing to the number of bridges necessary. Two ravines of considerable depth were passed to day; the first, about seven and a half miles from Tilley's is the rocky gorge through which the Pokiock stream runs down to the St John; it is very narrow, but of considerable depth, in some places amounting to sixty or seventy feet. On this stream there are several saw mills. The other, seven miles further on is called "Sullivan's Creek." It is spanned by a bridge of timber, resting on granite foundation, which was found to be necessary, as all the bridges put up over it in the usual style of the country had been carried away in floods. The remains of several of these bridges are still visible in the channel below the present bridge.

The mid-day halt was made to-day at a tavern on the Eel river, which is a tributary of the St John, separating the counties of York and Carleton. Here the road is only seven miles from the termination of the St Andrews railway at Canterbury, by which line "F" Battery of the 4th Brigade, Royal Artillery, was sent up country. Eel river is spanned by a covered bridge, and is navigable for boats for a considerable distance. After crossing it, the road passes through a more level and better cultivated country, but still close to the river. The party arrived at Woodstock about 6.30 p.m.; the men were lodged in a large building (capable of accommodating 1100 men) which had been hired as a barrack, and the officers were in a hotel. Woodstock is a town which is rapidly increasing, as it has extensive iron works in the neighbourhood. From it several roads diverge, one to St Andrews, one to Houlton in Maine, one to Fredericton, and the road up country. As the road now approaches the American frontier, it was considered

necessary to take great care to prevent desertion. On this subject, private directions had been given to the officer commanding before leaving St John, but an additional memo. on the subject was given to him here by Captain Percy of the 9th Foot, who was doing duty as Dep.-Asst.-Qr.-Mast.-Gen.* The precautions taken were to confine the men to barracks each night; and as they were generally fatigued with their journey, they did not grumble.

FIFTH DAY. *Monday, February* 10. *Woodstock to Florenceville, 23 miles.* Fifth day's march.

The weather continued as previously very clear and cold, the thermometer on starting standing at 15° below zero. One trifling case of frost bite happened to day, the only one that occurred during the ten days' march. Soon after leaving the town of Woodstock, the road ascends till it gets on to the table land, at the top of the hills above the river. Here the breeze was much felt as there was no sort of shelter from it. Soon, however, the road changed to its old character, constant ascent and descent, through endless ranges of "soft woods" overhanging the river. This day's march tested the strength of the sleds and the mode of packing and lashing, more than any other part of the journey did, the ascents and descents being so steep and the "cahôts" so numerous and deep. On arriving at Florenceville it was found that two of the gun sleds had the tranverse pieces which supported the trails, broken across, caused doubtless by the trails pitching a little when going over bad portions of the road. As previously explained, the trail lashings were of necessity very oblique, so that the pitching could not be entirely prevented. The broken pieces were replaced in a very short space of time, and the new pieces put in lasted till the end of the journey. The sled too which carried the store-limber wagon body got off the track, and the horses fell in the deep snow, but it was soon righted again. The mid-day halt was made at Mill's tavern, sixteen miles from Woodstock. The remainder of the road is of the same character, and the sameness of the scenery becomes somewhat tiresome, though it is all beautiful. Florenceville, a small settlement on the river, was reached about 5 p.m. It lies in the county of Carleton. The accommodation is as follows:—In the principal inn (Parker's), six officers and fifty men could be accommodated. Three other houses could accommodate respectively sixty, fifty, and twenty men, and if necessary some other officers could be accommodated in another house.

SIXTH DAY. *Tuesday, February* 11. *Florenceville to Tobique. 26 miles.* Sixth day's march.

The weather continued the same as usual, and the men were in the best health and spirits. The road to day hardly merits a description, being the same as that of the previous days, never distant from the bank of the river more than half a mile, and winding along through long woods of pines, firs, cedars, black and yellow birches, &c. On the

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* See Appendix, No. VI. p. 205.

opposite bank the scenery is of the same character, sloping hills thickly covered with wood, with here and there a few clearings and log huts. Some attempt had been made to repair the worst "cahôts" in the road, so the travelling was not so bad. The mid-day halt was made at Baird's tavern in Andover parish, eighteen miles from Florenceville, and the last eight miles of the road are comparatively level, so they were quickly got over, the party arriving at Tobique at 4 p.m. Tobique is a pretty village, distant only four miles from the States. The accommodation here is as follows:—Newcombe's inn, five officers and twenty men; two other houses ninety, and fifty respectively; and Mr Beveridge who resides here, is most willing to accommodate any officers in his house. The Tobique river which falls into the St John a few miles above the village, is the second largest tributary which it receives, and it can be ascended in boats till within a few miles of the Nipisiguit, which runs down into the Bay of Chaleur.

Seventh day's march.

SEVENTH DAY. *Wednesday, February* 12. *Tobique to Grand Falls* 24 *miles.*

The weather this day was much milder being dull and overcast, a little snow falling occasionally. The roads were therefore much easier. The character of the road too is somewhat different; for about four or five miles above Tobique it crosses over the Aroostook river by a substantial bridge, and then leaves the St John, and does not again touch it till Grand Falls. The Aroostook is the largest tributary of the St John. The country is leveller, though still hilly, and with the exceptions of a few clearings, covered with dense forest. A large log hut, built by a party of "lumberers," was passed shortly before coming to the mid-day halting place. The latter was a collection of poor houses ten miles from Tobique. The party arrived at Grand Falls about 5 p.m.

This village receives its name from the falls of the St John river, in its immediate vicinity. It is partly inhabited by French settlers which make their appearance here for the first time. The scenery of the falls is very fine. The river discharges its waters over a precipice nearly sixty feet high, and then pursues its course through a deep rocky gorge, with cliffs of great height on each side. This gorge is spanned by a fine wire suspension bridge about half a mile below the falls. The falls of course completely cut off the navigation of the upper river from that of the lower; but even above them the river is navigable for steamers for forty miles. All the "lumber" floated down the St John has to be conveyed past the falls by portage, otherwise it would be broken to pieces. The men were accommodated in a large building, the officers in a hotel. At this village a large hospital was arranged, in case any serious cases should happen on the march, but fortunately there were but few inmates.

Eighth day's march.

EIGHTH DAY. *Thursday, February* 13. *Grand Falls to Little Falls,* 36 *miles.*

The weather continued mild to-day, and the roads were much easier. After leaving the village, the road crosses the St John on the

ice above the falls, instead of passing over the suspension bridge, by which several hills are avoided. The river now forms the boundary between New Brunswick and the United States, and about three miles above Grand Falls, the boundary line of Maine, consisting of a broad track cut through the woods, is seen running up over the hill from the right bank of the river. As nothing but the river separates the countries, and as it is of course frozen over, the ease with which any man attempting to desert could get away, is evident, hence great precautions had to be taken. The character of the country and of the inhabitants changes as the road advances. The road at first runs along the top of a level plateau about half a mile broad, and about 50 ft. above the level of the river, consisting principally of cleared land, with occasional stretches of underwood, instead of forest. From the back of this plateau the hills slope up gently as before. Soon the road quits the river, and although it is never at any very great distance from it, yet it is not seen for the remainder of the day. It is also much more level, and the character of the scenery is tamer. The road is still full of cahôts and dangerous places. The settlers are nearly all French, and their national taste is evident in the style of their log huts, which instead of being left in the rough state externally as those down the country, are all neatly smoothed, and finished. The mid-day halting place, was Jenkin's tavern, eighteen miles from Grand Falls. The road is now in the district of Madawaska, so called from a river of the name, and passes over a large number of considerable streams which all flow into the St John. In the parish of St Basil, a few miles from Little Falls, there is a very handsome nunnery and Catholic church; and the country is thickly inhabited by French settlers. Little Falls, a village situated near the confluence of the St John and Madawaska rivers, receives its name from some rapids in the river St John which impede the navigation. The party arrived about 6 p.m. The officers were lodged in the house of Mr Emerson, one of the principal inhabitants, and the men in a large building nearly opposite. These houses are close to the river; the opposite bank being part of the State of Maine.

NINTH DAY. *Friday, February* 14. *Little Falls to Fort Ingall,* 37 *miles.* **Ninth day's march.**

The weather was very mild, and soon became overcast; and snow commenced to fall, lasting the whole day. This rendered all attempts to observe the country or road impossible. Here the road finally leaves the St John river, and now follows the right bank of the Madawaska river, which connects Lake Temiscouata, with the St John river, thus leaving also the American frontier and approaching that of Canada. The first ten miles of this day's journey lie along a perfectly level stretch of country, thickly covered with underwood, amongst which are the stumps of many large trees, which have been burnt. This level ground varies in width, and is at no great elevation above the Madawaska river, which is on the right of the road, but is not visible from it, for any great distance. On the left of the road, as far as could be seen for the snow, lies a high range of hills thickly

covered with wood; and on the opposite bank of the river, a gently sloping range of hills, partly wooded and partly cleared. About ten miles from Little Falls, near Trout stream, a small tributary of the Madawaska, the road crosses the boundary line, a broad track cut through the forest which cannot be mistaken, between New Brunswick and Canada. The moment it is crossed, the improvement in the road is manifest. Instead of the rough irregular road of New Brunswick,—full of holes, and with a ridge in the middle of it,—the Canadian road is smooth and level, and everything that could be desired. The cause of course is, that the Canadian government can afford to have the snow-plough and roller constantly at work on the roads; the government of New Brunswick cannot. Twenty miles from Little Falls, near where the Madawaska river issues from Lake Temiscouata, there is an inn and some houses on the river. The place is called the "Dègelé" by the French settlers, from the river being always open there in consequence of some hot springs: it is distant a few miles from the main road, but as no better place can be found, it was chosen as the mid-day halting place. After leaving this, the road becomes very hilly, running over a constant succession of hills, thickly wooded, and with no signs of clearings or cultivation anywhere. Soon the road strikes the Temiscouata Lake, and the scenery here appears to be very beautiful, but the snow that was falling thickly prevented all observation. This lake is a long narrow sheet of water, twenty miles long and from two to four wide, and is celebrated for the beauty of its scenery. Fort Ingall is an old blockhouse barrack, rapidly going to pieces, situated on the shore of the lake, about two miles from its head. It is surrounded by the remains of an old stockade; and a few rooms and a cookhouse had been cleaned out and furnished with beds of spruce boughs for the reception of the men. There are officers' quarters in the fort, but of course no furniture of any description. There are however some houses adjoining, and a French inn, where the officers were lodged.

Tenth day's march.

TENTH DAY. *Saturday, February* 15. *Fort Ingall to Rivière-du-loup, 42 miles.*

This the last, was the longest day's march of any. Fortunately the snow ceased and the weather was clear and beautiful. Between Fort Ingall and Rivière-du-loup there are two roads, one the old one, along which the telegraph wires run, is now impassable, at least in winter. The new road is at first tolerably level, running through underwood which grows round the burnt and blackened stumps of lofty trees, but soon begins to ascend through a wild hilly country, covered as usual with thick woods. The scenery becomes bolder and the road still ascends, passing on the left the Cabana Lake, from which a river runs into Lake Temiscouata. Twenty-one miles from Fort Ingall, the highest point of the road is reached, and from this there is an easy and rapid descent to St Francis, five miles further on. Here the mid-day halt was made. There is a French inn and some houses; and behind them a large log hut has been built for the accomodation of the soldiers, as at one time it was intended to break this last day's

stage into two. Here one of the sleds laden with harness, vats, &c. broke down in consequence of driving rapidly over a bad slew in the road just in front of the inn. The wooden pins of the sled gave way, as previously described,* and one of the runners became detached. The damage however was repaired in about twenty minutes. From this place the road continues hilly for a few miles. About ten miles from the journey's end, a fine view of the St Lawrence is obtained, with a bold chain of mountains on its northern shore. The last eight miles into Rivière-du-loup are almost perfectly level, but from the length of the day's march, the teams were somewhat done up, so the pace was slow, and the party did not arrive till nearly eight o'clock. Before entering the town, the railway terminus is passed, about two miles from it. Here the eighteen gun and equipment sleds were left for the night, along with the greater portion of the baggage.

The town seems a pretty, rising place; it is inhabited almost exclusively by French settlers. The men were lodged in a large house with a number of rooms; the officers were in a hotel.

SUNDAY, *February* 16.

Transferring the half-battery to the train. This morning, a party paraded and transferred the half-battery complete from the sleighs to the railway cars in three hours. A large open truck and a closed van were the only two cars supplied. The guns had the wheels put on, and also the store-limber wagon; and then, along with the wagons, and limber bodies, spare shafts, &c. were all packed on the open car, care being taken to remove all the hay in which the carriages had been packed, to prevent sparks from the engine catching in it. The ammunition, and harness and equipment boxes, &c. were packed in the closed van. The special train of which these carriages formed a part, left at 1 p.m. the same afternoon, and arrived at Montreal about 2 p.m. the day following.

Packing on train, and arrival at Montreal.

Conclusion. It must be carefully kept in mind that although this journey was performed without any accident or trouble of any kind, yet it does not follow that it could have been done equally successfully in all winters. The government of New Brunswick cannot afford to keep their roads in good order, so a heavy fall of snow if accompanied with drift renders them impassable for a long time. The inhabitants of the province declare that if it had been attempted last year, it would have been found impracticable; and also that by a strange coincidence, the present winter, 1861-62, and the winter of 1837, when troops were sent up before, have been the two mildest winters on record.

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* See p. 183.

APPENDIX OF ORDERS, MEMOS., ETC.

No. I.

Quarter-Master General's Office,
St John, New Brunswick,
February 3, 1862.

Mem.

Appendix of Orders, Memos. &c.

During the progress of "E" and "G" Batteries, R.A., the guns and equipment sleighs will be handed over on their arrival at the respective halting stations to the officer in charge, who will cause them to be parked and guarded in the usual manner.

The sleighs are not to accompany the horses to the stables.

By order,

(Signed) L. SHADWELL, Colonel,
Asst.-Qr.-Mr.-General.

Lt.-Col. Turner, C.B.,
Royal Artillery,
St John.

No. II.

Memorandum, for the guidance of officers commanding detachments of troops proceeding by sleigh from St John to Rivière-du-loup.

Officers commanding detachments of troops proceeding to Rivière-du-loup, will make the following reports to the Asst.-Quarter-Master-General at St John, at the end of each day's march :—

(1) By telegraph,—

The arrival of the troops at the new station, stating anything of an urgent or important nature.

(2) By letter,—

The health of the troops; the state of the weather and roads during the march; whether anything was wanting at the halting place of the previous night for the accomodation of the troops. He will add any remarks that may suggest themselves to him, regarding the arrangements for the men on the march.

The officer commanding the party will also leave a memorandum for the officer in charge of the detachment following him, containing any information which he may consider of service.

Should a detachment be unavoidably detained at a halting station, the officer commanding must immediately transmit a telegraphic message to that effect to the station in his front and rear to be *passed along the entire line of route,* so as to prevent confusion by crowding at any of the stations, but the detachments in front are not to be detained thereby. Another telegraphic message must be sent in like manner when the detachment causing the detention is ready to proceed, and the parties in rear will then continue their march. Should telegraphic offices not be established at any of the halting stations, a messenger must be despatched. Appendix of Orders, Memos, &c.

The detachment proceeding from Fort Ingall to Rivière-du-loup, should telegraph their probable time of arrival to the latter station, in order that the railway carriages may be in readiness for the party, and hot tea or coffee provided for the men.

One pair of moccasins per man will be issued to detachments of troops proceeding up country from St John, and the officer commanding each detachment will give a receipt for the same.

At Fredericton, Woodstock, and Little Falls, these moccasins will be handed over to the issuer of stores at the station, who will give a receipt for them to the officer in charge of the party, to whom he will issue a similar number for the use of the men, and for which he will take a receipt. This arrangement will be carried out along the whole line from St John to the Rivière-du-loup, where they will be returned.

By order,

(Signed) L. SHADWELL, Colonel,
Asst.-Qr.-Mr.-Gen.

Quarter-Master General's Office,
St John, 6th January, 1862.

No. III.

Should mid-day halting places be required, the following places are available between Fredericton and Rivière-du-loup :—

FREDERICTON :

1. A tavern in Kingsclear parish.

TILLEY'S :

2. Eel river tavern, close to the bridge.

WOODSTOCK :

3. Mill's tavern, Middle Simmonds parish.

FLORENCEVILLE :

4. Baird's tavern, Andover parish.

TOBIQUE :

5. Simon Ballard's and neighbouring houses (about ten miles from Newcombe's at Tobique).

Appendix of Orders, Memos, &c.

GRAND FALLS:

6. Jenkin's tavern, and Joseph Cyr's house.

LITTLE FALLS:

7. Dumont's house at the Dègelé.

FORT INGALL:

8. Saint Francis.

RIVIÈRE-DU-LOUP.

(Signed) L. SHADWELL, Colonel,
Asst.-Qr.-Mast.-General.

St John, New Brunswick.
5th Feb. 1862.

No. IV.

Abstract of district order, dated St John, New Brunswick, January 9, 1862, relative to the issue of extra rations of rum and groceries to the detachments on the line of march,—

1. They will be issued in small unbroken packages, in quantities to last from one *depôt* to another.

2. They will only be issued at *depôts*, viz.

Saint John,	Grand Falls,
Fredericton,	Fort Ingall,
Woodstock,	Rivière-du-loup.

3. At the intermediate *posts*, viz.

Petersville,	Tobique,
Tilley's,	Little Falls.
Florenceville,	

there are stores in cases of emergencies.

4. Officers commanding detachments will obtain from the commissariat officer at each depôt, *two* ration certificates (see page 203), *one*, shewing the period to which the bread and meat has been issued; the *other*, the number of rations of rum and extra articles, which the detachment has been provided with. The first will be given up at each post (intermediate posts included), where rations of bread and meat only may be drawn, and another similar certificate obtained. The second will in like manner be given up at the depôts, where the extra rations are issued, any excess in the previous issue, being of course accounted for; a further advance will then be made, and a certificate given.

5. Should these certificates not have been obtained, the officer commanding must give a certificate, for the accuracy of which he will be held personally responsible.

6. A supply of tobacco and soap is laid in at each depôt; they will be supplied to the men at cost price, on requisition and receipt in duplicate, of officers commanding detachments. Appendix of Orders, Memos, &c.

7. The following is the field ration:—

$1\frac{1}{2}$ lb. bread or 1 lb. biscuit.
$1\frac{1}{4}$ lb. fresh meat, or 1 lb. salt,
Tea $\frac{1}{6}$ oz., coffee $\frac{1}{3}$ oz., sugar 2 oz.,
Salt $\frac{1}{3}$ oz., pepper $\frac{1}{36}$ oz., rum $\frac{1}{64}$ gallon.

at a stoppage of 6*d.* for a soldier, and 4*d.* for an officer.

8. The rum kegs are to be preserved, and exchanged, or refilled at the depôts.

9. A pair of moccasins will be issued to each man, on receipt of officer commanding; to be exchanged at each depôt, and sent back by the return sleighs to the Asst.-Qr.-Mast.-General or other staff officer at the depôt in rear.

10. Candles and wood will be issued, where no agreement has been made for their supply. One candle to four officers or eight men. Firewood must not be wasted.

Form of Receipt. No. 1.

Post......................................
.... Regiment.

I certify that the following supplies have been issued to the dates specified inclusive:—

Bread or biscuit...... } To the........day of........1862.
Fresh or salt meat }

for ...... officers ...... non-commissioned officers and privates, and forage for ...... horses.

(Signature of Storekeeper.)

(Date)

Form of Receipt. No. 2.

Post......................................
.... Regiment.

I certify that the following number of rations of extra articles have been issued from this date inclusive:—

Tea..................	rations.	Pepper	rations.
Coffee	„	Suet	„
Sugar..............	„	Rum	„

No. of kegs to be returned.

for ...... officers ...... non-commissioned officers, and privates.

(Signature of Storekeeper.)

(Date.)

Ration returns of these forms are to be provided by the commissariat officers at each post or depôt, and are to be signed by officers commanding.

Appendix of Orders, Memos, &c.

No. V.

FREDERICTON,
Feb. 7, 1862.

Memorandum.

1. The detachment of troops due this day at Fredericton from Petersville, will be stationed in the barracks, Royal Artillery park, in rooms pointed out by the Barrack-master.

2. The guns and equipment sleighs will be parked at the Store Barracks under charge of one non-commissioned officer, and three gunners, R.A., to be furnished as a reinforcement to the guard at these barracks. Care will be taken that the guns and equipment sleighs are parked in separate divisions to avoid confusion in starting to-morrow morning.

3. Immediately on arrival at Fredericton, the officer commanding the detachment will order a non-commissioned officer from each corps to attend at the commissariat office, to settle for rations for the forward journey.

4. A non-commissioned officer from each corps will be furnished for gate duty at the barracks.

5. The detachment will proceed to-morrow morning to Tilley's, as follows:—

(1) A sleigh with the rations and cooks, one for each corps under a non-commissioned officer, Royal Artillery, will leave Fredericton at 6 a.m.

(2) The equipment with its detachment at 7 a.m.

(3) The remainder of the troops, together with the guns at 8 a.m.

6. The officer commanding the detachment will be careful to include in his telegram to head quarters, the strength of the officers as well as of the men.

7. Marching-in and marching-out states will be furnished on arrival and departure by each corps to the corporal of Royal Engineers in attendance.

8. With reference to the forward journey, one of the drivers is always appointed head teamster, for each train of sleighs, and the officer commanding the detachment will take care to enforce the order, that no sleigh shall be stopped for the purpose of watering or feeding the horses, or shall go on ahead except by permission of the head teamster. The head teamster will lead the line of sleighs, and will regulate the pace. Every sleigh will keep the sleigh in rear of it within hail, therefore should the non-commissioned officer in No. 1 sleigh see

No. 2 stop or fall to the rear, he will halt or slacken the pace of No. 1. Or should No. 4 sleigh halt, Nos. 3, 2, and 1 in front, will also halt until No. 4 is ready to go on again. The watering and feeding of teams will only take place by the permission of the head teamster,—halts and advances will be simultaneous along the whole line.

(Signed) C. FORDYCE,
Colonel.

No. VI.

Memo. for guidance of Officers Commanding detachments proceeding to Rivière-du-loup.

WOODSTOCK,
Feb. 9, 1862.

At Florenceville, Tobique, and Grand Falls, the greatest care and caution must be exercised to prevent desertion. No civilian can be permitted to enter the soldiers' billets on any pretence.

A guard will be mounted immediately on arrival.

On the line of march all soldiers are confined to barracks.

An officer will visit the billets every night, and satisfy himself that every man is present; *unceasing* vigilance on the part of the officers is demanded.

At Fort Ingall, officers commanding detachments will separate the baggage, only retaining with them what will be required for the night at Rivière-du-loup; the heavy portion of the baggage will be left at the railway station in passing, and much trouble and expense will thus be saved.

The senior officer alone, will telegraph on each night to St John.

By command.

(Signed) J. W. PERCY,
D.-A.-Q.-M.-Gen.

No. VII.

MEMORANDUM OF MOVEMENT.

Quarter-Master General's Office,
St John, 5th February, 1862.

Regiment.	Officers.	N. C. O. and Men.	Date.	Hour.	From	To	Mode of Transit.	Remarks.
"G" Battery, 4th Brigade, Royal Artillery.	3	99	6th February, 1862.	8·15 a.m.	Custom House Barracks.	Petersville.	Sleigh.	
63rd Regiment	2	61		8 a.m.	Permanent Barracks.			
Royal Engineers	...	1		8 a.m.				

By order,

For the information of
Lieut.-Colonel Turner, C.B., Royal Artillery,

(Signed) L. SHADWELL, Colonel,
Asst.-Qr.-Mr.-General.

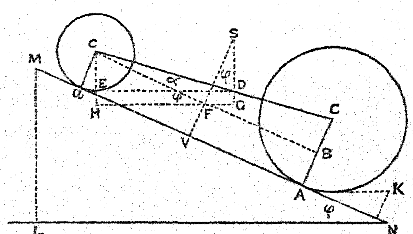
ON FINDING THE CENTRE OF GRAVITY OF A GUN ON ITS CARRIAGE AND LIMBER, OR OF A GUN ON ITS CARRIAGE UNLIMBERED.

By Lieut.-Col. H. H. MAXWELL, R.H.A.

I HAD occasion a few years ago to endeavour to find the centre of gravity of a gun on its carriage unlimbered, as a preliminary to the solution of another question. The method I pursued was a slight and obvious alteration in the following method of finding the centre of gravity of a four-wheeled cart, derived from Fisck's *Elementary Treatise on Mechanics of Solid Bodies*, and quoted in the *Treatise on Mechanics* by Joseph Dirschl, Vienna, 1857. As I have never seen this subject written of elsewhere, I have ventured to lay it before your readers.

1. Let it be taken for granted that the carriage as should be the case is symmetrically built and laden, the vertical plane passing through the middle point of both axles must be that in which gravity acts. If we run the carriage on to a platform such as MN (fig. 1), inclined to the horizon at

Fig. 1.



an angle ϕ, in such fashion that both axles shall be horizontal, and chock the hind wheels with wedges K; if, again, we suspend the ends of the axle-arms of the front wheels by the two ends of a chain, and attach the centre of this chain to one arm of a balance, and then increase the counterpoise in the opposite scale, until by the play of the beam the front wheels just lift clear of the inclined plane MN and no more, then, the weight in the scale, *less* the weight of the chain and the front wheels will indicate the vertical pressure, which the front axle exerts on the naves of its wheels. Let this weight be represented by p, and let us imagine an equal force at C acting vertically upwards; this force, after abstraction of the chain and front wheels, will keep in equilibrium the upper part of the carriage (that is, *less* the four wheels) and its load on the fulcrum C of the hind axle.

Let S be the centre of gravity and W the weight of the carriage (*less* its wheels) and its load, which acts in the line SD vertically downwards, then is

$$CD \,.\, W = cC.p.$$

Draw SV, ca and CA perpendicular and cB parallel to MN, let us take the co-ordinates of the centre of gravity,

$$aV = cF = x; \quad VS = y,$$

the radius of the front wheels $ca = r$, that of the hind wheels $CA = R$ and the distance between the axles $cC = a$, then is $FS = y - r$, and in the right-angled triangle cBC, putting the angle $BcC = \alpha$;

$$\sin \alpha = \frac{R - r}{a}.$$

Through D and F draw the horizontal straight lines DE and GH and through c the vertical straight line cH, then the angle $HFC = FSG = \phi$ and $HcD = 90^\circ - \phi + \alpha$, and we have in the right-angled triangle SGF

$$FG = FS \sin \phi = (y - r) \sin \phi,$$

and in the right-angled triangle cHF

$$FH = cF \cos \phi = x \cos \phi;$$

therefore

$$FG + FH = GH = DE = x \cos \phi + (y - r) \sin \phi.$$

Again, in the right-angled triangle cED,

$$cD = \frac{DE}{\cos(\phi - \alpha)} = \frac{x \cos \phi + (y - r) \sin \phi}{\cos(\phi - \alpha)};$$

consequently,

$$CD = a - cD = a - \frac{x \cos \phi + (y - r) \sin \phi}{\cos(\phi - \alpha)}.$$

If this expression be substituted in the above determined equation of moments, we have

$$ap = \left\{ a - \frac{x \cos \phi + (y - r) \sin \phi}{\cos(\phi - \alpha)} \right\} W,$$

$$\text{or} \quad x \cos \phi + (y - r) \sin \phi = a \left(1 - \frac{p}{W}\right) \cos(\phi - \alpha).$$

For any other angle of inclination of the platform ϕ', with which the pressure on the front axle is p', we have similarly,

$$x \cos \phi' + (y - r) \sin \phi' = a \left(1 - \frac{p'}{W}\right) \cos(\phi' - \alpha).$$

By the combination of these last two equations we finally find as values of the co-ordinates of the centre of gravity of the carriage *less* the wheels

$$\left.\begin{aligned} x &= a\left\{\cos\alpha - \frac{P\sin\phi'.\cos(\phi-\alpha) - P'\sin\phi.\cos(\phi'-\alpha)}{W\sin(\phi'-\phi)}\right\}, \\ y &= r + a\left\{\sin\alpha + \frac{P\cos\phi'.\cos(\phi-\alpha) - p'\cos\phi.\cos(\phi'-\alpha)}{W\sin(\phi'-\phi)}\right\}, \\ &= R + a\,\frac{P\cos\phi'.\cos(\phi-\alpha) - p'\cos\phi.\cos(\phi'-\alpha)}{W\sin(\phi'-\phi)}. \end{aligned}\right\} \quad \text{I.}$$

If the pressure P' on the front axle be determined when the platform is horizontal, then $\phi' = 0$; and hence we get from the formulæ I, the simple formulæ

$$\left.\begin{aligned} x &= a\cos\alpha\left(1 - \frac{p'}{W}\right), \\ y &= R + \frac{a\sin\alpha}{W}\{(p'-p)\cot\phi.\cot\alpha - p\} \\ &= R + \frac{R-r}{W}\{(p'-p)\cot\phi.\cot\alpha - p\} \end{aligned}\right\} \;\ldots\ldots\ldots\ldots \text{II.}$$

Further, if the carriage is equirotal, then $R = r$ and $\alpha = 0$, and we get from Equations II.

$$\left.\begin{aligned} x &= a\left(1 - \frac{p'}{W}\right), \\ y &= R + a\cot\phi.\frac{p'-p}{W} \end{aligned}\right\} \;\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{III.}$$

2. To ascertain the centre of gravity U of the carriage with all four wheels (fig. 2), let S be that of the carriage and its load but without the

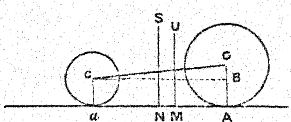


Fig. 2.

wheels; let c and C be the centres of gravity, and q and Q the weights of the fore and hind wheels, we shall have in the plane ac of the moments

$$aM(W + Q + q) = aN.W + aA.Q,$$

and for a plane Aa of the moments

$$MU(W + Q + q) = ac.q + NS.W + AC.Q;$$

or, putting, $aN = x$, $NS = y$, $aM = X$, $MU = Y$ and retaining the same notation as before in other respects,

$$\left.\begin{aligned} X(W+Q+q) &= aW + a\cos\alpha\,.\,Q, \\ Y(W+Q+q) &= rq + yW + RQ. \end{aligned}\right\} \quad (1^a)$$

Determining the values of X and Y, and substituting the previously ascertained values of x and y of Equations II., we have

$$\left.\begin{aligned} X &= a\cos\alpha\left(1 - \frac{p'+q}{W+Q+q}\right) \\ Y &= R + (R-r)\,\frac{(P'-P)\cot\phi\,.\cot\alpha - (p+q)}{W+Q+q} \end{aligned}\right\} \ldots\ldots\ldots \text{IV.}$$

These last formulæ will then answer for the determination of the centre of gravity of a gun and carriage limbered up. To determine that of a gun unlimbered, which is of importance in questions of the effect of firing on gun carriages. In such case $r = 0$, and $q = 0$, and the whole reasoning is equally applicable. For a gun unlimbered then

$$\left.\begin{aligned} X &= a\cos\alpha\left(1 - \frac{P'}{W+Q}\right), \\ Y &= R + R\,\frac{(P'-P)\cot\phi\,.\cot\alpha - P}{W+Q} \end{aligned}\right\} \ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{V.}$$

To try these formulæ practically I had a platform erected at an inclined plane, the vertical height ML being $51''\cdot25$ and the horizontal extent NL being $123''\cdot5$, or at an angle with the horizon of $22°.\ 32'.\ 14''\cdot7$ or ϕ. In the first experiment I ran a Bengal 9-pr. gun of 10 cwt. on its carriage* and unlimbered, trail end upwards, up the inclined plane, so that both trail and wheels rested on the platform; the wheels being duly chocked with wedges. I had the beam of a large balance rigged up with one end immediately over the trail and connected the end of the beam to the trail handles by the scale chains; and ran the scale-board itself between the chains, so as not to alter the equipoise. When all was ready, I gradually added weights until the trail just lifted off the platform and no higher. I then took a note of the weight. The gun was next run down on to level ground, and the end of the trail placed in the centre of one scale-board, and weights gradually added until there was equilibrium. To ensure accuracy I had square holes dug under the scale-boards so that the upper surface of the scale-board was on the same level as the ground on which the wheels stood. I then again noted the weights in the scale. I proceeded in the like manner with the 24-pr. howitzer 10 cwt.*

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* The 9-pr. and 24-pr. elevating screws were run down as far as they would go, giving respectively angles of 12°. 9′ and 13°. 33′.

The following are the data then for the calculation of the centre of gravity in both cases:—

BENGAL PIECES.

9-pr. 10 cwt.	24-pr. howitzer 10 cwt.
$a = 92''$,	$a = 88''$,
$p = 217{\cdot}6$ lbs.	$p = 205{\cdot}5$ lbs.
$p' = 308$,,	$p' = 329$,,
$W = 2489{\cdot}5$,,	$W = 2578$,,
$Q = 449$,,	$Q = 449$,,
$R = 30''$.	$R = 30''$.

$$ML = 51''{\cdot}25,$$

$$NL = 123''{\cdot}5,$$

$$\cot MNL = \cot \phi = \frac{123{\cdot}5}{51{\cdot}25} = 2{\cdot}4097561,$$

$$\phi = 22^\circ.\ 32'.\ 14''{\cdot}7\,;$$

$$\sin \alpha = \frac{R}{a} = \frac{30}{92} = 0{\cdot}3260870, \qquad \sin \alpha = \frac{R}{a} = \frac{30}{88} = 0{\cdot}3409091.$$

$$\alpha = 19^\circ.\ 1'.\ 53''. \qquad \alpha = 19^\circ.\ 55'.\ 56''.$$

Substituting the above values in Equations V.

$$X = 92 \cos \alpha \left(1 - \frac{308}{2489{\cdot}5 + 449}\right) \qquad X = 88 \cos \alpha \left(1 - \frac{329}{2578 + 449}\right)$$

$$= 92 \cos \alpha \times \frac{2630{\cdot}5}{2938{\cdot}5} \qquad = 88 \cos \alpha \times \frac{2698}{3027}$$

$$= 77''{\cdot}855. \qquad = 73''{\cdot}731.$$

9-pr. 10 cwt.

$$Y = 30 + 30\,\frac{(308 - 217{\cdot}6) \cot \phi \,.\, \cot \alpha - 217{\cdot}6}{2489{\cdot}5 + 449}$$

$$= 30 + 30\,\frac{631{\cdot}53 - 217{\cdot}6}{2938{\cdot}5}$$

$$= 34''{\cdot}226.$$

24-pr. howitzer 10 cwt.

$$Y = 30 + 30\,\frac{(329 - 205{\cdot}5) \cot \phi \,.\, \cot \alpha - 205{\cdot}5}{2578 + 449}$$

$$= 30 + 30\,\frac{820{\cdot}68 - 205{\cdot}5}{3027}$$

$$= 36''{\cdot}097.$$

In like manner by substituting the values of x and y of Equations III. in Equations 1^a, we shall get values of X and Y for obtaining the centre of gravity of an equirotal carriage such as those in use in the Artillery Service.

The above experiment was made with a view to getting data for the calculation of the strain on the axle of a carriage when the piece is fired. In this calculation I failed, owing to the difficulty of comparing impact with pressure. I commend the problem to the notice of better mathematicians.

CUPOLAS AND FORTS.

BY FRANCIS DUNCAN, M.A., LIEUTENANT, ROYAL ARTILLERY.

FELLOW OF THE GEOLOGICAL SOCIETY, AND D.C.L., KING'S COLLEGE, N.S.

IN the first paper on this subject, which appeared in the "Proceedings" of the R.A. Institution,* my object was more to generalize on the advantages of the plan I proposed; and to record the ideas which, from their simplicity, may have existed in the mind of any artilleryman or engineer, who has given the subject consideration. The notice taken of the former article by some of the military papers, encourages me to pursue the subject more into the region of details, and to enlarge on such of the advantages formerly mentioned, as seem of the greatest importance.

In an article which appeared in a recent periodical,† the writer labours, and successfully, to prove that old fortifications cannot resist new guns. But he at the same time goes on to quote the report of the Commissioners of the National Defences, that "the considerations respecting the progress, which is being made in the production of ordnance of increased power, tend to show that in all probability the relative value of forts opposed to ships will be greatly increased." This same opinion was expressed in my former paper, by saying "that fortresses evidently derive a higher ratio of benefit from improvements in artillery, when these improvements involve heavier guns and larger charges, than either ships, or armies in the field." But in entering on details on such a subject, the duty of the writer is to show the means by which such superior advantage is to be obtained, and when obtained, how to be most effectually employed.

In concluding the last paper, hints were thrown out as to the immense advantages to be derived by the use of the cupola on martello towers; and I shall best enlarge on these by illustration. The martello tower is most appreciated on a coast, round a harbour, or on an extended frontier like that of Canada. On a coast, as in a fortress, we must value the strength of the defences, as being not greater than their weakest point. So that, if we fortify *one hundred* miles of a coast accessible to an invading force, and leave *twenty* undefended which are equally accessible, we may consider the whole coast as far as resisting the landing of an enemy is concerned to be virtually undefended, and the expense of the incomplete defences to be practically thrown away. But there is a limit to the money a nation can expend in its fortifications, nor can it enclose itself within regular lines of fortification like a Chinese wall. Here then the martello tower comes in, and by placing

* Vide p. 107.

† Colburn's United Service Magazine. October, 1862.

these at intervals round such parts of a coast as an enemy can land on, we obtain the advantages of comparatively cheap and simple defence, and interference with the invader's base of operations, with the still greater one, that the destruction of one tower does not materially affect the others. And the enemy will either have to take the towers in detail, and thus give time to the invaded country; or by scattering their forces to capture several at once, they will weaken their powers of resisting any attack which the defending army might make upon them. Or, supposing,—as in these days of rail and telegraph we may easily suppose,—that sufficient notice had been obtained by the country attacked, to allow of the concentration of large bodies of troops on the spot where the enemy should land, what magnificent support would these towers afford to the defending army, what unequalled guns of position would their armament afford, and how great would the advantage be in having heavy artillery on the field in anticipation instead of having to delay the whole army, or to act with light pieces alone.

But in these days of rifled cannon all these advantages would be reduced to *nil*, did we leave martello towers as they now are. Some time ago, the R. A. Institution issued photographs of the result of a few rounds from rifled guns upon some of our towers which afforded melancholy evidence of the truth of the statement, that old fortifications cannot resist new guns. But let us do as suggested in the former article; let us surround the tower with a short steep glacis, and a corresponding deep ditch, forming a powerful rampart, and surmount the tower with a cupola, whose gun or guns would sweep with impunity the surrounding country, and could be depressed so as even to sweep the little glacis, should its capture be attempted by a *coup-de-main;* and we have a work whose capture would involve considerable delay,—whose fall would weaken the line of defence only by the unit of its own resistance, which would form a valuable support to the defending army, and which the invader would hardly dare to leave uninjured, should he advance into the interior of the country. The details of placing the cupola on such a tower would be simply those of placing it on the deck of a vessel; its working would be simple, the small number of men required to serve the gun when under so effectual a cover would leave ample magazine accommodation; the cupola itself would render the tower bomb-proof; the height of the glacis and its steepness would save the walls of the tower, and to a great degree also the lower part of the cupola from direct fire; and the only danger would be a chance shot striking the muzzle of the gun, or the cupola receiving some injury, which would interfere with its revolving, neither of which are contingencies so probable as to require special provision. To this, however, we shall again allude, when we discuss the effect which the enemy's bombardment would probably produce on the cupolas in a fortress. We shall merely mention in passing that a perusal of the reports of the experiments carried on with rifled ordnance at Eastbourne against a martello tower, and, in a less degree, the similar experiments at Bexhill with smooth-bores, will satisfy any one that a tower unprotected by some sort of earthen bank or glacis is merely a target for the enemy's artillery. And the diminished expenditure of iron and gunpowder which is required with rifled guns to produce the same result against stonework, which a much greater amount was required to effect with smooth-bore ordnance, relieves an invading army of the necessity of carrying so enormous an amount of ammunition, as in former

times they would have been obliged to do; while at the same time it would encourage them to attack forts, which they would formerly have left alone, rather than expend the ammunition which they would reserve for the later movements of their campaign.

We said that round a harbour or dockyard these towers would be found highly advantageous.

In the discussions between the advocates of fixed and floating harbour defences, the great argument used by those in favour of the latter was, that a vessel could speedily steam past a fortress, and offer a small mark for the fire of its artillery; and that, once past, it could with impunity shell the town or dockyard, the entrance to which the fort was meant to defend. And yet, Colonel Boxer, an advocate for floating harbour defences, says and says truly in a paper written by him in the "Proceedings" of the R.A. Institution,* that "if in any particular case an enemy's ship cannot attain its object until it has silenced the fire of a fort, then, in such a case, a permanent fort should, no doubt, be resorted to, in preference to a floating battery, as a means of defence." Now, as a fort at the entrance of a harbour can be easily passed, either by taking advantage of the night, or by great speed, and as the surrounding of our harbours with long lines of fortification would be too expensive an idea to be entertained, a happy medium seems to exist in the employment of towers, surmounted by large rifled guns under cupolas, and placed at the entrance, and at intervals round the harbour. By this means, the impunity with which a ship, once past the forts at the entrance of the harbour, could shell both town and dockyard disappears, and it becomes exposed to a fire concentrated on it from all directions; from heavy ordnance used at ranges which constant and accurate measurement and practice have rendered familiar to the gunners, while the task of silencing so scattered a series of forts, offering a small mark, and with a diverging fire, would be too hopeless for it to attempt. As, however, at the entrance of our harbours, and on the heights round our dockyards, the soil might frequently be too rocky to permit of the ditch and glacis, which would be used along a level coast; I would suggest that the face of each tower (whose height above the harbour did not remove it from the effect of the enemy's fire), which would be exposed to the fire of ships entering the harbour, should be covered with iron plates such as many propose to cover the scarps of our large works with, but which in the case of the scarps would be far too expensive, from their great length. I consider that such a defence as this, would employ fewer men, and be much more destructive from the concentration of its fire, than the most powerful forts at the entrance of a harbour; and, while infinitely less expensive, would be just as effective as lines of works surrounding the dockyard; and to this we add the already mentioned advantage of each fort being self-contained, and not weakening each other by their individual capture. At the present crisis in fortification, when men are wavering between the advantages of different systems and ending by distrusting all, it is possible that a system, like the one just proposed, possessed of the two great virtues, simplicity and cheapness, might recommend itself to those interested in the important question of harbour defences. And as the towers could be constructed in a much less time than the usual style of works, it is presumed

* Vide p. 93.

the cupola and the expense magazine, which as on shipboard it is proposed to have immediately below.

Two other questions that were raised in the critiques referred to were the probable effects of a shot on the working of a cupola, and the results of the concussion of the firing upon the gunners within. So to speak, these questions were fortunately decided in the engagement between the *Merrimac* and the *Monitor;* for although repeatedly hit at very close quarters, we do not hear that the revolving apparatus of the cupolas received any material injury, to prevent its working; and the question of concussion and its effects was hardly raised. I certainly heard one or two people in America assert that the men who manned the guns suffered from bleeding at the nose and ears, but the assertion lacked proof and was never confirmed; while the instant order to construct many more vessels on the same principle seems to give a contradiction to any depreciatory rumours. However, it is hardly probable that with the immense amount of our mechanical resources, any difficulty on these two points would be too great to overcome.

In fine, although as in all new plans there are difficulties which suggest themselves, there is no lack of means of obviating them; and at a time when the fortifications at Spithead have been checked for further consideration, and when indeed everything seems *in transitu,* it is to be desired that some one of greater experience would take this question into serious consideration; and have it pressed on the notice of the Defence Commission, and, through them, of the Government.

OBSERVATIONS UPON CHANGES THAT MUST BE INTRODUCED INTO WORKS OF DEFENCE TO ENABLE THEM TO KEEP PACE WITH IMPROVEMENTS IN ARTILLERY. READ AT THE R. A. INSTITUTION, NOV. 14, 1862.

BY CAPTAIN C. S. HUTCHINSON, R.E.
PROFESSOR OF FORTIFICATION, R.M.A.

THE subject which the Committee of this Institution have done me the honor of asking me to remark upon this evening, is one which has necessarily occupied considerable attention for some time past, and upon which much has been thought and written. I propose in the following paper to notice briefly some of the various suggestions that have been offered, with such remarks as may appear necessary, trusting that many points will present themselves for interesting discussion.

It will be most convenient to divide the subject into three parts, viz.—(1) field works, (2) permanent works, and (3) coast batteries.

Field Works.

As regards profile it does not seem probable that much change will be necessary, further than that the thickness of parapets should be increased as far as time and opportunity will allow, to resist the greatly increased charges carried in elongated shells. In some cases, such as in parapets on the brow of a hill with other hills in the neighbourhood, where a low parapet of 5 or 6 ft. high might have been formerly sufficient to cover troops from any point within range, an additional command would now have to be given if the adjacent hills, available to the enemy, were within present ranges.

With regard to plan, it will be more than ever desirable to direct the principal forces of works so as to avoid enfilade fire, and to provide frequent traverses as a defence against curved fire, and segment shells. The salients of lunettes or other works forming a line with intervals may, if the ground admits of it be placed at greater distances, by which the points of attack will be reduced, and a smaller number of men suffice for the defence.

The more frequent use of field works, particularly for the advanced posts of armies in the field will, it is believed, be largely called for in future campaigns, and it has been well suggested by Col. Bainbrigge, in Volume XI. of the "R.E. Professional Engineer Papers," that detachments of the engineer train consisting of horses or mules provided with packsaddles for conveying tools, each pair led by a mounted soldier, should be organized for accompanying the advanced guard of an army.

Permanent Fortification.

Under the head of profile, the principal changes called for seem to be the following :—First, a large increase in the thickness of parapets, not so much to resist the penetration of elongated projectiles (of which we are still

comparatively ignorant), but as in the case of field works to render the effects of shells less destructive, and to have more earth at hand for the repairs of damages. This thickness has been made from 20 to 27 ft. in some of the new works at the dockyards. Some recent French works give 21 ft. Secondly, the lowering of the top of the scarp, so that instead of being in a plane passing through the crest of the glacis and the most commanding point the enemy can occupy within range, it may be some feet below that plane, to avoid the risk of any considerable height of it being breached by a distant curved fire. This will be particularly necessary where an independent wall or one with a *chemin des rondes* may be employed. As this lowering of the escarp will, if the bottom of the ditch is horizontal, render necessary a very high counterscarp, the bottom of the ditch may be sloped upwards towards the counterscarp, so as to reduce the height of the latter. With the same object of diminishing the risk from distant curved fire, the ditch should be made as narrow as practicable, so as to bring the crest of the glacis as near the wall as may be.

While the lowering of the scarp and narrowing of the ditch are necessitated by the improvements in distant curved fire, breaching the escarp from batteries on the crest of the glacis will be also thus rendered more difficult.

Captain Tyler, R.E., in a lecture delivered by him at the United Service Institution, in March, 1860, advocates the abandonment of the escarp altogether, substituting for it a counterscarp, about twice the usual height. By this arrangement a besieger after blowing in the counterscarp, which, whether it were a high or low one, would be an operation of much the same difficulty, would have no further obstacle to overcome, and would be spared the danger and delay of constructing breaching batteries on the crest of glacis.

With regard to trace, as far as flanking the ditch is concerned, it does not seem desirable to increase the length of lines of defence beyond the range of case, or at any rate of grape shot, unless it is found that the segment shell or some similar projectile can be made to produce equally certain effects at short as well as at long ranges.

It will be absolutely essential that the flanking works, if casemated, should either be so placed that their walls and embrasures should not be liable to injury from distant fire from batteries in the prolongations of the ditches, (by which from the experience gained in Germany in 1857, and at Juliers in 1860, they could certainly be destroyed), or, should it not be practicable to trace the ditches so that their prolongations may fall on ground that the enemy cannot take up, the fronts of the casemates must be then either iron plated, or a plan may be adopted, recommended by M. Piron, an officer of the Belgian Engineers, in a work called "La Fortification Eclectique," and carried out, I believe, in the new works at Diest in Belgium. It consists in placing a mask or counterguard parallel to, and about 10 yds. from, the wall of the casemate, with arches running through it, the piers of which coincide with those of the casemate. The height of the arches is regulated so as to conceal the embrasures from a battery on the crest of the glacis. To prevent the debris of the piers and arches, when being breached, from masking the embrasures, a small ditch may be excavated under the front of each arch. M. Piron calculates that with a counterguard 20 yds. thick, it would take 88 hours continuous firing from two 24-prs. at a range of 400 yds., to destroy

one brick pier 6 ft. thick, but as he fires his guns only five times an hour, his estimate of resistance seems considerably too high. The disadvantages of a mask of this kind are that it prevents the guns in the casemate from at all opposing the construction of the counter or breaching batteries on the crest of the glacis, and that very soon after breaching commences it must, unless the excavations under its arches are made of a very considerable depth, and the expense of its construction thereby much increased, begin to mask the fire of the embrasures on the bottom of the ditch. The most practical way therefore of protecting the front walls of flanking casemates seems to be to construct them of iron. Recent experiments have, I believe, shewn that the distance between the piers at the front of the casemate may be reduced from 12 to 10 ft. and yet allow of the working of a heavy gun; and the question at present under consideration is how most economically and efficiently to close an opening of this width, and perhaps cover the front ends of the piers. I understand that the system of iron planking and cross planking as recommended by Captain Inglis is likely to prove most easy of application, and most efficient.

As to the terreplein of works it will be necessary to provide an ampler supply of traverses than formerly, and to increase the distance between the guns, so that the merlons may oppose more resistance to the explosion of shells.* In any faces or flanks which cannot by their trace be secured from enfilade or reverse fire, blindages of a permanent character, such as haxo-casemates, must be employed. Though considerably more space than of old will thus be required, there can be no doubt a few guns well secured are superior to a larger number more exposed. If the fronts of haxo-casemates are exposed to fire, an iron protection would be necessary to the masonry, and also to the throats of embrasures. The cheeks of earthen embrasures will of course offer but feeble resistance to the accurate fire of rifled guns; iron shields should therefore be secured to the parapet extending a few feet to either side of the embrasure. A practical mode of doing this is pointed out by Captain Inglis in the last volume (XI) of the "R.E. Professional Papers." Another method of securing guns on ramparts is indicated by Lieut. Duncan, R.A., who proposes, in a paper lately issued in the "Proceedings" of this Institution, using for the purpose Captain Coles' cupolas. These might no doubt be employed with advantage at important points where great lateral range is required, such as salients, but they would be too costly for anything like general use; and one of the advantages claimed for them, that of doing away with the necessity of outworks, can hardly be conceded, since one of the main uses of the latter is to bring a reverse and flanking fire on a besieger who should be hardy enough to attempt the main work before taking the outworks in front of it. Captain Inglis also, in the paper before alluded to, advocates the use of revolving wrought-iron screens for guns in salients.

With regard to the employment of iron in escarps, the enormous expense (calculated by Captain Inglis at about £4 to £5 per foot *super*), would of course prevent the idea being entertained of ever using it largely for such a purpose. The plating of any small portion of an escarp, such as

* As much as 37 ft. is allowed in some of the new works.

that opposite the ditch of a ravelin, which it is impossible entirely to screen against a besieger's curved fire, might however be desirable. Without using iron much may doubtless be done to render walls less easily breached than heretofore, by the more general use of counter-arched revetments. Captain Scott, R.E., suggests the construction of these entirely of cement concrete in the manner shewn in Vol. XI. "R. E. Professional Papers," p. 238; where the gravel and lime are abundant on the spot, an escarp of this kind can be built at a cost of about half the price of an ordinary revetment of brickwork of the same height. It is the opinion of Captain Fowke, who has had great success in concrete constructions, that from the peculiarity of concrete, it being as it were monolithic, it is peculiarly adapted for the construction of escarps, as in the event of a large part of the front of an escarp being breached, it is by no means certain to bring down the superincumbent mass of the wall. Sir John Burgoyne is also of opinion that concrete forms so connected a mass, that it will bear great openings without the upper mass falling. It seems therefore most desirable that experiments should be carried on against concrete walls with a view to ascertain their powers of resisting breaching, as in the only ones recorded, viz. against a bomb proof in the Marshes in 1835, and against a wall in the United States in 1854, the concrete had not been given time to dry properly, and was not compounded of the most suitable lime.

While speaking of concrete, it may be mentioned that at these same experiments in the United States, blocks of lead concrete (formed by pouring molten lead into moulds nearly filled with heated fragments of brick and stone), were used in the construction of casemate embrasures, and were found to offer great resistance to the fire of heavy guns at short ranges. Colonel Totten reported that heavy balls with high velocities penetrated into it little more than their diameters, moulding for themselves a symmetrical bed, in which they were found crushed. They caused no cracks through the mass, and detached only very small and harmless splinters. He considered that next to wrought iron, it was out of a great number of substances experimented on, the best. Similarly favourable results having I believe been arrived at in some recent experiments at Copenhagen, lead concrete would seem well worthy of a trial either as a substitute for, or in combination with, wrought-iron in casemate embrasures.

The remarks that have been already made will of course apply both to the works forming a continued enceinte, or to detached works. With regard to these latter, it is perhaps hardly necessary to observe that they must, if intended to protect a dockyard or arsenal from bombardment, be advanced much more than was formerly considered necessary, while their distance from each other may be increased. Those now under construction or consideration according to the plan drawn up by the Defence Commission, vary for example in distance from the works they are intended to protect, from 2000 to 9000 yds. Their general outline is more or less that of flat lunettes, the gorges being occupied by casemated keeps. The drawings before you shew the general arrangements of one of these works. It will be observed that the flanking of the ditch is obtained principally by caponiers; and it is conceived that one result arising from the improvements in artillery will be the adoption of the polygonal trace in preference to the bastioned for the important fronts of works, owing to the far greater facility of tracing the work, so that the faces and caponiers may be protected from distant enfilade

fire, than exists in the case of the faces and casemated flanks of bastioned fronts.

A heavy and well protected fire of artillery from a fortress will no doubt compel a besieger to make a more frequent use of mining operations than has hitherto been customary. A more general employment of countermines may therefore be fairly considered as another consequence of the improvements in Artillery. In the last edition of the French "Aide Mémoire du Génie," the construction of branches and chambers by means of borers, similar to those used for artesian wells, is advocated. In favourable ground 70 ft. may be bored in four hours, and a chamber formed without difficulty capable of holding 400 lbs. of powder. M. Piron, in the work before alluded to, conceives (and probably with justice), that great advantage to the defence will arise from a large use of these artesian mines.

Coast Batteries.

With regard to the third point which it was proposed to notice, viz. changes in coast batteries, the use of uncovered masonry in parapets, embrasures or the fronts of casemates in positions near to which an enemy's ships could advance, must to a large extent be abandoned, constructions of iron, or of masonry protected with iron being substituted; the thickness of earthen parapets in similar positions must be largely increased, and shields of iron used, as before pointed out, for strengthening earthen embrasures. Positions from which any long channel could be enfiladed, and which would have formerly been considered too distant, might now be advantageously occupied by earthen or other batteries.

The adoption of iron for casemate fronts, and of iron screens for strengthening earthen embrasures, disposes of a difficulty which formerly gave a ship a certain advantage over a shore battery, viz. the large opening of the embrasures of the battery compared with the small ports of the ship's side. It now of course becomes practicable to make the one as small as the other.

The exterior opening of existing casemate embrasures, which in some amounts to as large an area as 54 square feet, yet admitting a horizontal traverse of only about 40°, might by a judicious use of iron throat pieces, combined with that of Colonel Colquhoun's raised racer and imaginary pivot, be reduced to 10 square feet, or even less, without impairing their lateral range.

Having now touched upon some of the principal changes in works of defence which appear to me to be called for by improvements in Artillery, I will conclude by expressing the hope that an interesting discussion may ensue, and by thanking the Committtee of the Institution for providing these opportunities for debating upon professional subjects. I do not know that I need apologize for the brevity of this paper, for I think that a short paper followed by a full discussion is more interesting than the contrary.

ACCOUNT OF EXPERIMENT CARRIED ON AT SHOEBURYNESS, ON THE 29TH DECEMBER, 1862, AGAINST A SHIELD CONSTRUCTED ON THE PRINCIPLE PROPOSED BY CAPTAIN INGLIS, R.E., REPRESENTING AN IRON EMBRASURE, FOR EITHER CASEMATED OR OPEN COAST BATTERIES.

[CONTRIBUTED BY CAPTAIN E. J. BRUCE, R.A.]

THE target measured 11′ in length by 8′2″ in height, and contained an embrasure 3′ 6″ high × 2′ 4″ wide. It was composed of vertical planks of hammered iron of various dimensions, namely, 1′ 11″ × 8″, 1′ 11″ × 7″, 1′ 7¼″ × 8″, 1′ 7¼″ × 7″, and 1′ 7¼″ by 6″, backed by horizontal planks of rolled iron, 14″ wide by 5″ thick, and secured by 3-in. screw bolts and some 3-in. rivets.

One half of the target represented half of a shield 12′ wide, the other half one 10′ wide.

It was secured to a frame consisting of four vertical pieces 1′ 2″ × 4″, and two horizontal pieces 1′ 2″ × 5″, and the whole was supported at either end by a boiler-plate strut, having a base of 3′, and made up of a web of 1-in. plate and angle irons 8″ × 5″ × 1″ and 5″ × 5″ × 1″. These struts were riveted to sill pieces 14″ × 4″, and these again secured to a cross beam 18′ long, 11″ wide, and 3″ deep, and placed 6′ in rear of the shield. The cross beam was heavily weighted, and secured at each end by a mass of masonry, and formed the sole means of holding the shield in its place. The boiler-plate strut, at the end representing the 10′ shield, was made to splay outwards at an angle of 15° from the perpendicular,* as this would be necessary in actual practice to admit of the required traverse of the gun (70°). The other strut stood perpendicular to the shield.

Between the surfaces of the front and rear, layers of Plank's sheet lead were introduced, weighing 6 lbs. per foot superficial; and under the nuts of the screw bolts several descriptions of elastic washers were used. Some of these washers were of the nature of buffers, composed of 3″ of india-rubber inside a strong wrought-iron cylinder; others were of coils of wire rope similarly confined; and in other cases, several lead washers, and washers of iron and brass were used.

The shield was made at Messrs Mare's Works, at Millwall.

The planks were numbered from 1 to 5, commencing on the left.

The following guns were used in the experiment :—

One 120-pr. Whitworth rifled gun. | One 110-pr. Armstrong rifled gun.
One 68-pr. smooth-bore gun.

The following shot struck the shield :—

From 120-pr. Whitworth gun	One round-ended solid cast-iron shot 119·5 lbs. weight. One flat-ended homogeneous solid shot, 130 lbs. weight.
From 110-pr. Armstrong gun	Three solid cast-iron shot, 110 lbs. each. Two solid cast-iron shot, 68 lbs. each.
From 68-pr. gun	Five solid cast-iron shot, 67 lbs. each.

Range 200 yds.

* This arrangement will not be required, as all shields are to be 12′ wide.

Number of round.	Nature of ordnance.	Projectile. Nature.	Weight in lbs.	Form.	Length.	Charge in lbs.	Elevation.	Range in yds.	Deflection.	Effects. Depth of indent in inches.	Diameter of indent in ins.	Remarks.
1	68-pr.	s.s.*	...	...	...	16	23′	200	...	1·6	9·4	Struck No. 2 plank 5·5″ from the right side and 2′ 9·5″ from the top of the plank; the side of the plank was bulged out ·5″ in a length of 1′; the indent was partly on a rivet; the lead between the planks was squeezed out a good deal at the side of the embrasure. At the back (facing the back of the target), immediately to right of embrasure, the top rivet had its end (which was slightly broadened or bevelled) chipped off. A through bolt, to right of embrasure (*i.e.* No. 2 bolt from top in that row), had a thin iron washer bruised over the nut; a through bolt, No. 2 from the top of the right row of all, had the lead washers pressed out a little; a through bolt, No. 3 from top of right (the same row), had its nut worked loose.
2	„	„	...	...	...	„	„	„	...	1·55	9·5	Struck No. 1 plank 4″ from the right side and 1′ 5·5″ from the top; the plank was driven in 1·25″ at the top and forced out ·6″ from plank No. 2; a narrow crack extended from the right edge of plank to the top of indent; the indent extended for ·5″ on to plank No. 2, the edge of which was bulged in for a length of 5″. At the back, a small rivet head holding an iron strap or band against angle iron inside top of right strut, broken off. The lead washers of through bolt, No. 2 from top of right row, more squeezed up, or compressed; angle iron, uniting to right strut, very slightly bent or curved back.
3	„	„	...	...	...	„	„	„	...	1·55	8·5	Struck plank No. 4, 4″ from the left side and 2′ 5″ from the top; the shot struck partly on No. 3 plank, which was bulged ·5″ for a length of 6″; No 4 plank started out ·5″ from No. 3; ·6″ broken off the face of the lower right-hand rivet over the embrasure. At the back, rivet at bottom of embrasure, left side, head scaled off; lead lining between backing and plank, squeezed out on left side of embrasure.
4	„	„	...	...	...	„	„	„	...	1·	10·5	Struck at the junction of plank No. 3 and the plate over embrasure, and 1′ 3·5″ from the top, 4″ of indent being on No. 3 plank; a small crack from the edge of plank, and one ·9″ long, on the centre of indent. At the back, no damage visible.
5	„	„	...	...	...	„	„	„	...	1·75	...	Struck No. 5 plank 4″ from the top and 3·5″ from the left side; indent on plank No. 4, 1·1″; No. 4 plank was bulged at the side for a length of 6·7″, the greatest width being 1·5″; plank 5 was driven in ·5″ at the top for a length of 6″ and was cracked at the top for a length of 6″ from the indent towards the right side, the crack being at 1″ below the surface of the plank. At the back, lead washer of upper through bolt, 2nd row from left, compressed and broken.
6	110-pr Armstrong	cast-iron	110	...	...	14	„	„	12′R	1·05	7·	Struck No. 1 plank 6·75″ from the left side and 3′ 5″ from the bottom; the plank was cracked through its thickness at the side, extending 1·1″ into the plank which was also bulged out at the left side ·25″ for a length of 8″; one bolt above indent started ·2″. At the back, four small rivet-heads off, on outside angle iron of strut (next the target); small rivet-head off side brace, at base of strut (inside); also small rivet of strut broken.

* Service shot.

Number of round.	Nature of ordnance.	Projectile.				Charge in lbs.	Elevation.	Range in yds.	Deflection.	Effects.		Remarks.
		Nature.	Weight in lbs.	Form.	Length.		′			Depth of indent in inches.	Diameter of indent in ins.	
7	110-pr Armstrong.	cast-iron.	110	...	...	14	23	200	12′R	1·15	7·5 × 7	Struck No. 2 plank 8·4″ from the left side and 4′ 1″ from the top. No damage visible on the front beyond indent made. At the back, No. 2 rivet from top right of embrasure, started about ·1″. Washer of through bolt below it, squeezed up slightly.
8	„	„	„	...	...	„	„	„	„	1·15	7·25	Struck No. 3 plank, 2′ 9″ from the top and 7·5″ from the left side, partly on a bolt-head; the bolt-head below the one struck, driven in ·25″. At the back, the lead between planks and backing, to left of embrasure, a little more pressed out.
9	„	„	68	...	...	16	15	„	8′R	2·3	8·25	Struck the left edge of No. 1 plank 3′ 4·5″ from the top, 6·25″ of indent being on the plank; the plank was cracked on the inside in two places in rear of indent for a length of ·5″ At the back, exterior angle iron (right strut), slightly cracked; and bevelled backing piece (allowing for slew of strut) cracked through.
10	„	„	„	...	...	„	„	„	9′R	2·	...	Struck at junction of planks 1 and 2, 7″ of indent being on No. 1 and 1·8″ on No. 2, the indent being 2′ 1″ from the bottom of the shield. At the back, through bolt, No. 2 from top, right of embrasure, thin iron and lead washers set back a little over the nut; wire washer worked in a little under the lead between the lead and the screw of bolt.
11	120-pr Whitworth.	„	119·5	R. E. †	16·5	20	„	„	nil.	1·8	7·	Struck plank No. 1, at 3·75″ from the side and 7″ above last round, measuring from centre to centre of indent; no damage to the shield either at front or back.
12	„	H.M. ‡	130·	F. E. §	13·5	25	18	„	„	2·	9·5	Struck No. 2 plank, 8″ of the diameter of the indent being on the plank; the left edge of the plank was bulged out 2″ in a length of 7·5″; the shot broke up into several pieces. At the back, brace lowest but one, inside of right strut detached, and its two rivet-heads broken off; rear part of strut itself at foot, slightly shaken; slight widening between adjacent parts of planks and supports in vicinity of blow.

† Round-ended. ‡ Homogeneous metal. § Flat-ended.

CRIMEAN MEMORIAL FUND.

THE following paper relating to the "Crimean Memorial Fund" has been recently transmitted to all Subscribers within reach, under Resolution II. of the General Meeting of August 21st.

Explanatory Statement.

AUGUST, 1862.

1. THE sum raised from all sources for the Royal Artillery Crimean Memorial Fund including the munificent donation of £2000 from two ladies, a contribution of £150 from Her Majesty and the late lamented Prince Consort, and accruing interest, amounted on the 30th June, 1862, to £4028.

2. After unsuccessful endeavours to procure the foundation of a local Institution for the benefit of soldiers' widows and orphans, it was resolved by a General Meeting, held at Woolwich, 26th April, 1858, to devote the whole of the donation of £2000 and what more might be necessary, to the purchase of eight perpetual presentations to the "Soldiers' Daughters Home" at Hampstead, and with the remainder to erect a monument on the Royal Artillery parade ground, at Woolwich. To these arrangements, being a deviation from the original design, it was necessary to ask her Majesty's approval, which was graciously signified through Colonel Phipps on the 19th April, 1858.

3. A Resolution of 27th April, 1858, provided,—

> "That the surplus if any, after deducting the sum of money set apart for the monument, should be appropriated to such charitable purposes as may hereafter be decided on."

4. The design of Mr Bell, R.A. was selected by a majority of votes at a General Meeting on 8th January, 1859, and a sum of £672 provided in the votes of 1858-9, representing the value of Russian gun metal, granted by the Government for the execution of it. This monument, a figure of Honor of heroic size, was erected in January, 1862.

5. It was originally expected that the casting might be performed in the Royal Arsenal, and in consequence of the non-fulfilment of this expectation, the following Resolution was carried unanimously at a General Meeting on 15th February, 1862:—

> "That the sum of £200 be presented to Mr Bell the sculptor, over and above the sum of £1500 guaranteed to him for the Statue designed, executed, and erected by him, in consideration of his having been led to expect that the casting would be done in the Royal Arsenal."

On the same occasion, at the request of Major-General Tulloh, the Committee of which he was President, was relieved from its duties, and the following Committee formed to carry out further details, and to take charge of the balance remaining in the Treasurer's hands for any further outlay.

BREVET-COLONEL LEFROY, R.A.
LIEUT.-COLONEL HENRY, R.H.A.
MAJOR ANDREWS, R.H.A.

6. The original intention of Mr Bell was to place the Statue facing south, in front of the centre archway, at about 30 ft. distance, and to lay out the entire front of the parade on a regular design, introducing guns and other trophies in harmony with the architectural features of the building: when the pedestal came to be erected, it was deemed that this situation would obstruct the parade, and it was placed on the site originally occupied by the Bhurtpore gun, which was moved 28 yds. forward, the Statue facing the Barracks. A majority of subscribers present on the 15th February, 1862, being of opinion that the first position was the best, it was contemplated to appropriate the greater part of the balance in hand to the removal of the monument if the permission of H.R.H. the Commander-in-Chief could be obtained. H.R.H. did not approve of the change, and signified in the following letter his opinion in favour of leaving it where it now stands, which decision the Committee and Subscribers present have respectfully accepted as final.

Removal of the Crimean Memorial Statue from its present site to a position within 25 *or* 30 *feet of the Centre Arch, R.A. Barracks.*

COMMANDANT'S OFFICE,
Woolwich, May 15, 1862.

SIR,

In reply to your letter of the 24th April, and its enclosure from Mr Bell on the subject stated in the heading. I am directed by the Major-General Commanding to request you will be good enough to inform the Committee of the Crimean Testimonial Fund, that the letters were laid before His Royal Highness the General Commanding-in-Chief, and that on his recent visit to Woolwich, His Royal Highness gave his personal attention to the subject.

Having examined the Statue on its present—and after inspecting the proposed site—His Royal Highness expressed his opinion in favour of leaving the Crimean Memorial where it now stands: first, on the grounds that he deems it a great ornament to the front of the Barracks; and secondly, that its removal would cause a considerable encroachment on the available parade ground. His Royal Highness regretted therefore that he could not concur in the views of the Committee.

Sir Richard Dacres desires me to convey this opinion of the Commander-in-Chief through you to the President and Members of the Committee.

I have the honor to be,
Sir,
Your most obedient Servant,
GEORGE T. FIELD, Major,
Dep.-Asst.-Qr.-Mr.-Gen.

Major Andrews, R.H.A.,
Secretary and Treasurer,
Crimean Testimonial Fund.

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7. A General Meeting was held 21st August, 1862, to consider what should be done with the balance,

Major-General Sir R. DACRES, K.C.B., in the Chair,

when the following Resolutions were successively put, and carried unanimously:—

Moved by Colonel Lefroy, seconded by Colonel Sir David Wood, K.C.B.

1. "H.R.H. the Commander-in-Chief having withheld his consent to the proposed removal of the Crimean Memorial Statue from its present position to the position originally intended by the Sculptor, in front of the Central Arch, the Subscribers present are of the opinion that the best use of the balance in hand will be to appropriate a sum not exceeding £60 to the improvement of the base of the Statue, and the remainder to the erection of three Crimean Memorial Windows in the Chancel of the New Garrison Church."

Proposed by Major-General Sir R. Dacres, K.C.B., seconded by Colonel Sir David Wood, R.H.A.

2. "The foregoing Resolution to be printed, together with the balance sheet of the accounts, and a condensed explanation of the present position of the Fund, and transmitted to every subscriber in Great Britain, America, and the Mediterranean, with a blank form on which to communicate his assent or dissent. A majority of votes, to be verified at a future General Meeting, to decide whether the Memorial Windows shall be erected."

LIEUT.-COLONEL HENRY, MAJOR FIELD, CAPTAIN FORBES.	To be scrutineers, to report to the Meeting.

Proposed by Sir R. Dacres, seconded by Major Field.

3. "That the duty of selecting Orphans for the Presentations to the "Home" at Hampstead, be confided to the Committee of the Regimental Charitable Fund, preference being always given to orphans of soldiers, who served in the Crimea, or have died on active service elsewhere; a communication to be addressed to the several Brigades with a view to the names of candidates being brought forward in good time."

Moved by Captain Forbes, seconded by Major Milward.

4. "That the attention of the subscribers be called to the Resolution of 27th April, 1858, that they may be fully informed of the intention of the Subscribers then present, with regard to the balance of the fund; and as the balance is so small, that it is proposed to set the resolution aside in favour of the present proposal. That steps be also taken to circulate a photograph of the Statue, and of the proposed Memorial Windows in the Church, for the information of Subscribers."

On the 31st December, the Scrutineers appointed at the General Meeting, proceeded to examine the answers received, and declared the vote as follows:—

Against the appropriation of any part of the balance for Memorial Windows		30
In favour of the appropriation	136	
Received since	5	141
Majority		111

Steps will accordingly be taken by the Committee to carry out this decision.

J. H. LEFROY,
For the Committee.

4th January, 1863.

CRIMEAN MEMORIAL FUND.

THE COMMITTEE IN ACCOUNT WITH THE SUBSCRIBERS.

Cr.

Date		£	s.	d.	£	s.	d.
1858	Paid for Eight Presentations to the Female Orphan Asylum, Hampstead				2100	0	0
1859 July 20,	Paid J. Bell, Esq., Sculptor	500	0	0			
1860 Nov. 16,	" "	500	0				
1862 Jan. 23,	" "	250	0	0			
Feb. 21,	" "	250	0	0			
	Do. specially voted	200	0	0			
					1700	0	0
	Sundry small expenses				5	1	6
	By balance in hand, 1st March, 1862, £248 12*s.* 8*d.* Consols, at 90				223	15	5
					£4028	16	11

Dr.

Date				£	s.	d.	£	s.	d.	£	s.	d.
1855 Dec. 21,	Received of per Aberdeen Bank									2034	7	5
	Further subscriptions from 2 young ladies									16	6	1
	Her Majesty the Queen						100	0	0			
	H.R.H. the late Prince Consort						50	0	0			
	Messrs Cox & Co.						50	0	0			
	Officers, Royal Artillery						866	3	0			
	N.C. Officers and Men, Royal Artillery						391	14	6			
	Sundry Donations						26	3	0			
	Unappropriated working pay						44	2	8			
										1528	3	2
1856	By Dividend	July	on	2222	4	5	31	2	2			
1857	"	Jan.	"	"	"	"	31	2	2			
"	"	July	"	3293	3	5	47	19	2			
1858	"	Jan.	"	3650	0	0	53	3	1			
"	"	July	"	"	"	"	53	12	0			
1859	"	Jan.	"	1403	3	0	20	12	2			
"	"	July	"	1920	0	7	28	4	0			
1860	"	Jan.	"	1394	8	1	19	15	8			
"	"	July	"	"	"	"	20	0	10			
1861	"	Jan.	"	944	8	1	13	11	6			
"	"	July	"	"	"	"	13	12	8			
1862	"	Jan.	"	"	"	"	13	12	8			
										346	8	1
	By Profit on Purchase and Sale of Stock									103	12	2
										£4028	16	11

March 1, 1862.

NOTE.—A subscription since received and the July dividend, bring the balance up to about £237.

ON THE APPLICATION OF RIFLED CANNON TO THE OPERATION OF

BREACHING UNSEEN DEFENCES

BY HIGH ANGLE FIRING.

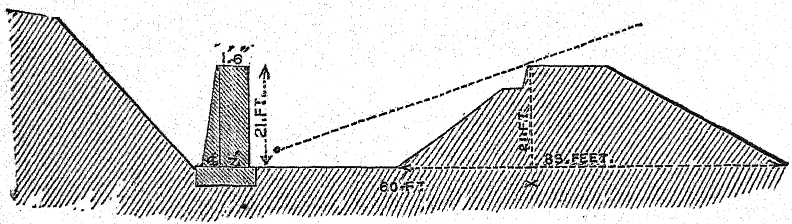
By Colonel LEFROY, R.A., F.R.S.

1. The present notes have reference to a question which arose on one of the preceding papers, when it was read a few weeks since at this Institution, and which was expressed in the following terms. "What is the greatest amount of curve that can be given to the Armstrong projectile, still preserving its power of penetration, and limited to what range?" The question had reference to the practicability of breaching masonry concealed by earthwork in front of it: as for example in firing over the crest of a glacis against an escarp unseen; and it is evident that in replying to it we must take the case of some particular projectile, and assume some definite resistance. For reasons which will presently appear, the 12-pr. and 20-pr. guns may be at once given up, as too light for the task. I shall assume therefore that the battering gun is not less in calibre than a 40-pr., and the escarp built of good brickwork.

2. In this form the question is. What are the smallest 40-pr. charges which will secure a serviceable degree of penetrating power at given distances? To have a considerable descending angle we must have high angles of elevation. To combine high angles of elevation with a limited range we must use a small charge; the smaller the charge that will do the work, the lower in vertical descent may we go, and the greater the choice of position for the battery. The famous experiments made in this garrison by order of the Duke of Wellington, in 1822 and 1824, furnish the first and most obvious standard of comparison.

The experimental practice of 1822, it will be remembered, was at a screen, and chiefly intended to furnish data for an actual operation of breaching. I extract an account of it from a manuscript in my possession in the handwriting of the late Sir Alexander Dickson, a name never to be mentioned by the Artilleryman without honour. It seems to be the draught of a report, but whether of a report actually rendered does not appear. Referring the reader to the Appendix (p. 239) for this document, it will be sufficient to say that it concludes by stating that the 10-in. howitzer, 8-in. howitzer, and 68-pr. carronade had proved themselves the most efficient pieces for this description of fire, and by recommending further experiments with them against an actual Carnot's wall. The angle of elevation was to be 15°, and the charges adjusted accordingly; however, as we shall see presently, it was not actually so great. The wall was erected in the summer of 1823. It was 21 ft. high, 7 ft. thick at the bottom, and 6 ft. thick at the top, with a frontage of 30 ft.,

strengthened at either end by a counterfort 4 ft. square, there was one loop-hole about the centre. It was covered by a counterguard of earth of the same height, the crest of which was 60 ft. distant: as shewn by the annexed section.



Scale for the profile $\frac{1}{480}$ or 40 feet to 1 inch.

3. In the instructions to the officer commanding the battery, the object of the experiment was stated to be "to determine whether the detached wall, which is covered by a counterguard, and not visible from the batteries, can be breached so as to render an assault practicable." The instructions go on to say, (2) "The ordnance used are 10-in. and 8-in. iron howitzers, firing live shells filled with powder, and 68-pr. carronades firing solid shot. (3) The howitzers and some of the carronades are on garrison carriages placed on raised traversing platforms, solely with the view of raising these pieces to the correct level; the rest of the carronades are merely on garrison carriages placed on common platforms, the difference of level being disregarded. (4) The ordnance are all proposed to be fired at an elevation of 15° above the crest of the counterguard, and the charges, which will not be changed, are regulated accordingly, as the shot and shells are wished just to graze the crest; the elevation will be varied in any trifling degree to accommodate itself to this intention, but when the exact elevation for each battery shall have been determined by careful observation of the first few rounds, this elevation will be steadily adhered to during the whole firing. . . (8) The batteries will as much as possible be fired in salvoes, this mode of firing being evidently the most favourable for breaching the wall. (9) The fuzes for the shells are intended to be so cut as to ensure that the shells strike the wall before they explode. . . ."

4. The report of the practice has been printed by Sir Howard Douglas in his "Observations on Modern Systems of Fortification" (1859), but as that work may not be at hand, I reproduce it in the Appendix, p. 242. The ranges, elevations, and charges were as follows:—

Three 10-in. iron howitzers at 600 yards; charge 1 lb. 3 oz., elevation $12\frac{1}{2}$°, reduced on the third day of practice to 1 lb. 2 oz., elevation $13\frac{3}{4}$°.

Three 8-in. howitzers at 400 yards; charge 11 oz., elevation $13\frac{1}{2}$°.

Eight 68-pr. carronades firing shot, at 400 yards; charge 1 lb. the first two days, reduced to 14 oz. the third day; elevation 13° to 14°.

The 10-in. and 8-in. shells were at first fired with their full bursting charges of 5 lbs. and $2\frac{1}{2}$ lbs respectively; but in consequence of some danger apprehended from the splinters, these were reduced to 2 lbs. 14 oz., or 3 lbs. for the 10-in.; 1 lb. 14 oz. or 2 lbs. for the 8-in. howitzer. The general result was that out of 3436 rounds fired, 202 shells and 289 shot took

effect on the wall, being about *one seventh* (0·146) of the whole; out of the remaining 2945 rounds, 1000 took effect on the counterguard, and 608 on the rampart behind the wall; the breaching effect is entirely due to the 491 rounds which struck the wall itself. Many shots were noted to pass a little to the right or left which would have struck a defence of less limited frontage, and have contributed to the result.

One hundred rounds per piece, 1400 in all, made a practicable breach 14 ft. wide; 50 more rounds per piece, 2100 in all, made the breach complete in every respect. The rubbish was then cleared away both before and behind, when 85 rounds per howitzer, and 100 per carronade (1910 rounds) completed the demolition of the part which remained.

5. Such then having been the effect produced by shot weighing 66·2 lbs., and shells weighing respectively 90 lbs. and 48·5 lbs., fired with low velocities, let us proceed to compare their effective powers with those of our existing rifled cannon projectiles. It is necessary for this purpose to ascertain their initial velocities, which has been done by Lieut. W. H. Noble, R.A., with Navez electro-ballistic apparatus, as follows:—

TABLE I.

Nature.	Length of bore and chamber.	Calibre.	Shot or shell.	Charge.	Initial velocity V.
	in.	in.	lbs.	lbs. oz.	ft.
68-pr. carronade	61·7	8·05	66·2	1 0	323
10-in. howitzer...	57·2	10·00	90·0	1 3	306
8-in. howitzer...	45·7	8·00	48·5	0 11	288

The next table contains the value of Wv^2 for each of the above projectiles, and the velocity which will give the same value for the 40-pr., 70-pr., 7-in. howitzer or 110-pr. gun, and 7-in. mortar shells. Here v is the remaining velocity on impact.

TABLE II.

Nature.	Smooth bores.			Equivalent velocity for rifled common shells.			
	W	v	$\frac{Wv^2}{g}$	40-pr.	70-pr.	7-in. mortar.	7-in. howitzer or 110-pr. gun
	lbs.	ft.	tons.	ft.	ft.	ft.	ft.
68-pr. carronade.	66·2	284	73·8	362	278	246	226
10-in. howitzer...	90·0	253	80·0	377	289	256	236
8-in. howitzer...	48·5	245	40·6	269	190	182	168

6. We see at once that very moderate velocities will give 40-pr. common shells and still lower velocities give 70-pr. or 110-pr. common shells, breaching powers which measured by equality of Wv^2 shall be on a par with those

employed in the experiments of 1824; their relative powers are not in fact expressed by this simple comparison; but the corrections, as we shall see below are all in favour of the rifled projectiles, it remains to enquire what are the charges which will give these velocities, and to ascertain whether such charges are compatible with high angles of elevation, and high angles of descent, at moderate distances.

The following Table contains a number of observations which have been made of the initial velocity of shells fired from rifled ordnance with very small charges. The observations were made and the results calculated by Lieut. W. H. Noble, R.A.

TABLE III.

Decimal value $\frac{C}{P}$	12-pr. 11·75 lbs.		20-pr. 21·5 lbs.		40-pr. 40·5 lbs.		70-pr. 69·62 lbs.		110-pr. gun, 7-in. howitzer 103·87 lbs.		7-in. mortar. 87·56 lbs.	
	Charge.	V	Charge.	V	Charge.	V	Charge.	V	Charge.	V	Charge.	V
	lbs. oz.	ft	lbs. oz.	ft.	lbs. oz.	ft.	lbs. oz.	ft.	lbs. oz.	ft.	lbs. oz.	ft.
·0114	...	...	...	...	...	...	...	...	...	...	1 0	287
·0201	...	...	...	...	...	...	...	...	2 0	407*	...	...
·0213	0 4	404	...	...	...	...	...	...	...	...	...	...
·0218	...	...	0 7·5	360	0 14	411	1 7·3	408	2 3·5	397	2 14	395
·0228	...	...	...	...	...	...	...	...	...	...	2 0	406
·0248	...	...	0 8·6	397	1 0	449	1 10·8	440	2 8·5	441	2 1	441
·0318	0 6	500	...	...	...	...	...	...	...	...	...	...
·0342	...	...	...	...	...	...	...	...	...	...	3 0	498
·0385	...	...	...	...	...	...	...	...	4 0	576*	...	...
·0435	...	...	...	...	1 12·5	630	...	...	...	...	...	...
·0456	...	...	...	...	...	...	...	...	...	...	4 0	575
·0570	...	...	...	...	...	...	...	...	...	...	5 0	647
·0638	0 12	796	...	...	...	...	...	...	...	...	...	...
·0648	...	...	...	...	2 10	805	...	...	...	...	...	...
·0684	...	...	...	...	...	...	...	...	...	...	6 0	704
·0851	1 0	962	...	...	...	...	...	...	...	...	...	...

7. It appears that a charge of *one forty-fifth* the shell's weight is sufficient to give an initial velocity of about 400 ft. a second to all these projectiles except the 20-pr. shell, which takes rather more: we have seen above that no shell of 40 lbs. and upwards requires so high a velocity as 400 ft. to contain a greater amount of *vis viva* than any of the shells employed in 1824. It now remains to be seen whether so small a charge is compatible with uniformity of range and accuracy of direction. The following Tables contain the results of actual practice made under the direction of the Ordnance Select Committee to determine the point. Two charges were fixed on for the 40-pr., namely 14 oz., which is rather more than *one fiftieth* (·0216), and 1 lb. Two charges in the same proportion to their respective shells were fixed on for

* The 110-pr. gun is not likely to be put to this service, but I have included with the 7-inch howitzer, two determinations with this piece, which is 24 inches longer in the bore than the howitzer, but is in other respects comparable with it.

all the other pieces. The ranges of the different pieces differ perhaps more than might have been expected under such circumstances, owing no doubt to the unequal capacity of the different chambers, and the differences in the lengths of the guns, but they are far more regular than those of smooth-bored pieces with reduced charges; and they concur with the previous observations given in the Report of the Ordnance Select Committee, which I am permitted to quote in the Appendix, p. 246, in proving the great superiority of rifled ordnance for this as for almost every other service of war. A Table will also be found in the Appendix, p. 251, giving the elevations for each 100 yds. deducible from this practice. That the pieces employed are very unnecessarily heavy for the duty, will occur to every one. The same reasons which led to the employment of smooth-bored howitzers under certain circumstances, instead of guns, will when rifled gunnery attains its full development, cause rifled howitzers to be added to our material, to throw shells with small charges for high angle firing, and to occupy positions which do not require or cannot take, so large and costly a piece as a rifled gun of the intended calibre.

When we make rifled pieces for charges not exceeding those usual with howitzers, it will scarcely be necessary to make them of wrought-iron, cast-iron will probably be strong enough for such purposes—the questions therefore opened up by this enquiry embrace a wider field than is perceived at first glance.

TABLE IV.

Date.	No. of rounds.	Elevation.	20-pr.							
			Charge.	Mean reduced time of flight.	Ranges.			Mean difference of range.	Mean observed deflection.	Mean reduced deflection.
					Min.	Max.	Mean.			
1863.		°	lbs.	sec.	yds.	yds.	yds.	yds.	yds.	yds.
January 29	5	8	0·469	3·92	373	451	413	18·4	0·80	0·44
February 5	5	10	,,	4·31	441	486	459	12·0	8·44	0·44
do	5	12	,,	4·95	459	547	510	30·0	8·76	0·68
February 9	5	15	,,	6·02	507	545	528	12·2	5·06	0·76
January 29	5	8	0·535	4·20	466	519	494	21·2	0·84	0·36
February 5	5	10	,,	5·02	508	601	542	27·6	9·12	0·30
February 9	5	12	,,	6·00	589	696	648	35·5	4·84	1·56
do	5	15	,,	6·82	647	722	694	21·0	4·38	1·02

TABLE V.

			40-pr.							
January 29	5	8	0·875	4·28	514	536	525	7·6	2·04	0·60
February 5	5	10	,,	4·16	560	690	626	45·2	1·72	0·42
do	5	12	,,	5·69	575	721	653	41·4	2·36	0·68
February 9	5	15	,,	7·11	780	830	799	12·8	0·88	0·90
January 29	5	8	1·000	4·55	576	634	616	18·4	1·80	0·48
February 5	5	10	,,	5·23	680	714	699	7·6	1·68	0·38
February 9	5	12	,,	6·55	813	861	*839	18·0	1·65	1·05
do	5	15	,,	7·66	965	1002	999	12·2	1·12	1·48

* Mean of four rounds.

Table VI.

Date.	No. of rounds.	Elevation.	70-pr.							
			Charge.	Mean reduced time of flight.	Ranges.			Mean difference of range.	Mean observed deflection.	Mean reduced deflection.
					Min.	Max.	Mean.			
1863.		°	lbs.	sec.	yds.	yds.	yds.	yds.	yds.	yds.
February 9	5	8	1·461	4·06	458	512	481	19·0	1·72	0·14
February 11	5	10	,,	4·70	514	547	537	9·4	1·80	0·24
February 9	5	12	,,	5·56	545	654	616	33·2	1·72	0·10
do	5	15	,,	7·23	760	905	818	42·6	4·60	0·40
do	5	8	1·672	4·22	530	578	543	14·0	1·60	0·32
February 11	5	10	,,	5·24	648	698	665	15·6	1·32	0·38
February 9	5	12	,,	6·07	725	835	791	44·0	2·44	0·52
do	5	15	,,	7·88	948	990	969	9·5	5·80	0·24

Table VII.

			7-in. howitzer.							
1863.										
January 28	5	8	2·219	4·16	431	515	486	29·8	3·24	0·12
do	5	10	,,	5·04	571	611	599	17·2	5·52	0·66
do	5	12	,,	5·75	588	664	629	28·8	7·80	0·64
do	5	15	,,	7·46	840	912	877	20·2	13·00	0·48
do	5	8	2·535	4·42	573	597	581	6·0	3·88	0·62
do	5	10	,,	5·18	604	670	636	22·2	5·48	1·22
do	5	12	,,	6·32	728	841	803	30·6	9·56	0·84
do	5	15	,,	8·08	991	1128	1059	53·2	15·88	0·82

Table VIII.

			7-in. mortar							
1863.										
January 28	5	8	1·879	4·32	485	524	507	12·4	2·92	1·38
do	5	10	,,	5·23	620	654	636	11·4	3·32	3·18
February 4	5	12	,,	5·94	642	752	696	25·2	5·04	4·66
do	5	15	,,	7·34	794	874	836	24·2	3·84	2·36
January 28	5	8	2·148	4·60	545	611	592	18·4	3·52	3·44
do	5	10	,,	5·30	637	712	678	30·2	3·88	3·60
February 4	5	12	,,	6·34	758	832	798	24·4	3·08	2·42
do	5	15	,,	8·02	938	1022	977	27·6	4·28	4·68

8. The foregoing comparison takes no account of the difference in the velocity of the smooth-bore and rifle shells on striking, of the difference in their diameters, or of the aid to penetration afforded by the rotation of the rifle shell, when it strikes point foremost. According to the French experiments the resistance to an elongated projectile is only *two-thirds* of the resistance to a sphere (Didion, §177), and the penetration of a round shot and

an elongated shot of the same weight striking with the same velocity into earth or masonry, will be as $\frac{2}{D^2}$ to $\frac{3}{D^2}$, practically it is hardly worth while to encumber the question with these considerations, for which we have insufficient data; so far as an inference may be drawn from a limited number of good penetrations observed in demolishing the two martello towers at Eastbourne* and Bexhill,† in 1860: rifle shot certainly penetrate in a higher ratio than would be given by the rule—"Directly as *vis viva,* inversely as the square of the diameter;" but those rifle projectiles had a velocity more than double the velocities we are contemplating, and a proportionably more rapid spin. I think it is sufficient therefore to point out that the low velocity shells from rifled guns will doubtless on the above grounds, have an advantage over spherical projectiles; but to what extent can scarcely be stated in the absence of direct experiment. Their greater capacity for bursting powder is obvious, and greatly augments their relative effect.

9. This superiority does not rest entirely on hypothesis. The Prussian Government two years ago took advantage of the demolition of the Fortress of Julich or Juliers, to make certain experiments bearing upon the present enquiry on a large scale; unfortunately, while it duly occurred to the British Government that this was a very important military operation, and advantage was taken of the friendly permission of the Prussian authorities to send Engineer Officers to witness it; it seems to have been overlooked that it was equally an artillery experiment, and no British Artillery Officer was sent there. We have however a very full account published by Captain Weigelt, Commissioner from the Brandenberg Artillery, and which has been translated by Lieutenant de Cetto, R.H.A., from whose MS. I extract the following particulars:—

EXPERIMENT 1.—17th September, 1860.

Two brass 12-prs. rifled, calibre 4·674 English inches, firing shells of 27 lbs. at 1072 yds., charge about 2·1 lbs., breached a brick wall 2 ft. 9 in. thick in 32 rounds (16 per gun), of which only 8 took effect. The profile of the work is shewn in Fig. 1.

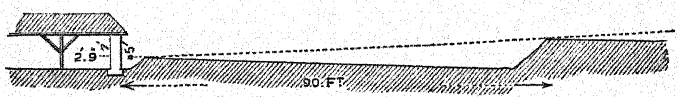


Fig. 1.

The wall was 7 ft. high, and completely covered by a counterscarp 90 ft. distant; but of such trifling relief that the angle of descent did not necessarily exceed 5°; as two feet of the base of the wall were covered by the counterscarp of its own ditch, the space to be breached was reduced to 5 ft. in height.

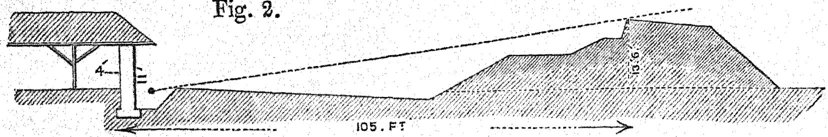
* Report of Breaching Experiments at Eastbourne. (Special Paper, Sept. 8, 1860).

† Vide Vol. II. p. 397.

Experiment 2.—17th September, 1860.

Four iron 12-prs. rifled, with the same charge and projectile made an opening 10 ft. wide and 6 ft. high in a brick wall 4 ft. thick at 1105 yds. The expenditure of ammunition was 64 rounds (16 per gun), but only 47 shells took effect. The profile of the work is shewn in Fig. 2.

Fig. 2.

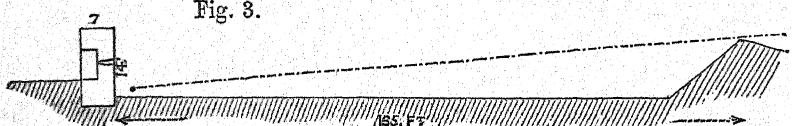


The wall was 11 ft. high, of which $1\frac{1}{2}$ foot was covered, and the whole was hidden from view by a parapet 13 ft. 6 in. high, at a distance of 105 ft.; requiring slightly larger angles of descent than in the first experiment, but still not exceeding 6°.

Experiment 3.—17th September, 1860.

The two brass and four iron 12-prs. of the preceding experiments were employed to breach a wall at 694 yds. distance. It was 7 ft. thick and 14 ft. high, supported at intervals by counterforts 4 ft. thick, and covered from view by the crest of a glacis at 135 ft. distance, as shewn in Fig. 3.

Fig. 3.



In this case it was not even necessary to diminish the service charge, and a complete breach was effected with an expenditure of 132 shells, the descending angle being under 3°.

If we compare the above profiles with the profile of the Carnot wall breached at Woolwich in 1824, it will be seen that they prove but little as to the capabilities of rifled guns for the service under consideration. The walls were slighter than will often be met with, the great distance and the slight relief of the covering works permitted the employment of charges and angles of descent which deprive the problem of all practical difficulty.

So far as they go however, they concur with what has been advanced above, to shew that caponnieres and concealed or sunken escarps derive no additional value in fortification from the introduction of rifled guns, which are quite as capable of breaching them as the smooth-bored ordnance employed so successfully for that purpose in 1823, and will do it under great advantages from their greater uniformity of range and the larger bursting charge of the shells.

APPENDIX. No. 1.

COPY OF A DRAUGHT OF REPORT OF AN EXPERIMENT AGAINST A SCREEN REPRESENTING THE WALL OF A FORTRESS, ACCORDING TO CARNOT'S SYSTEM. DATED WOOLWICH, OCTOBER 24, 1822.

1. The experiment commenced on the 2nd August, 1822, and continued till the 24th September following, during which period 1167 rounds of ammunition were fired from the following natures of ordnance, viz:—

	Length. ft.	Weight. cwt.	qrs.	lbs.
24-pr., iron	9	48	0	0
8-in. howitzer, iron	4	20	2	2
68-pr. carronade	5	36	0	0
10-in. howitzer, iron	5	39	2	20
8-in. mortar, iron		8	1	0

These pieces were each fired at ranges of 400 and 500 yds. distance from the crest of the counterguard in front of the wall.

2. The following is a statement of effect of the total number of 1167 rounds fired:—

	Rounds.	
Grazed short	417	
Took effect on wall	377	Rather less than one third.
Went over wall	373	
Total	1167	

Of the number of 377 rounds that took effect on the wall 116 rounds struck the wall at or below 12 ft. from the top, being only one-tenth of the number of rounds fired; but in stating this unfavourable result, it is necessary to observe that every allowance is to be made for loss of effect, by frequent change of the pieces of ordnance used, as well as alteration in the charges, elevations, and stations they were fired from, particularly in the commencement of a difficult operation, when many of the rounds were thrown away in experiments as to the best charges.

3. For the purpose therefore of forming a just opinion of the effect of this experiment, it is requisite to take it into consideration, in three points of view, as follows:—

(1) The individual effect of each piece of ordnance.

(2) A comparison of effect from 400 yds., and from 500 yds.

(3) With regard to the best angle of elevation to be used.

The following is a statement of the individual effect of each piece of ordnance, in explanation of the first point.

	Rounds fired.		Rounds that took effect.		Proportion.
24-pr.	217	....	53	....	$-\frac{1}{4}$
8-in. howitzer......	270	....	81	....	$-\frac{1}{3}$
68-pr. carronade...	320	....	112	....	$+\frac{1}{3}$
8-in. mortar	180	....	56	....	$-\frac{1}{3}$
10-in. howitzer ...	180	....	75	....	$+\frac{2}{5}$
	1167		377		

From this it appears that in individual effect, the 68-pr. carronade and 10-in. howitzer have performed best.

The second and third points will be best explained by the table annexed.

4 Abstract of effect against the wall of a fortress according to Carnot's plan, classed to shew the practice at different ranges and elevations.

Ordnance.	At 400 yards.												At 500 yards.												Total number of rounds fired from each gun.	Total rounds struck wall 12 ft. from top.
	10° or under.						15°						10° or under.						15°							
	No. of rnds.						No. of rnds.						No. of rnds.						No. of rnds.							
	Grazed short.	Took effect on wall.	Went over wall.	Total fired.	Struck wall at or below 12 ft. from top.	Proportion that took effect 12 ft. from top.	Grazed short.	Took effect on wall.	Went over wall.	Total fired.	Struck wall at or below 12 ft. from top.	Proportion that took effect 12 ft. from top.	Grazed short.	Took effect on wall.	Went over wall.	Total fired.	Struck wall at or below 12 ft. from top.	Proportion that took effect 12 ft. from top	Grazed short.	Took effect on wall.	Went over wall.	Total fired.	Struck wall at or below 12 ft. from top.	Proportion that took effect 12 ft. from top.		
24-pr.........	33	25	49	107	1	$\frac{1}{107}$	...	...	...	...	...	...	52	28	30	110	4	$\frac{1}{27}$	..	..	..	..	..	...	217	5
8-in. how....	40	42	28	110	11	$\frac{1}{10}$	8	14	8	30	6	$\frac{1}{5}$	36	8	16	60	...	...	24	17	29	70	9	$\frac{1}{8}$	270	26
68-pr. carr.	46	46	48	140	8	$\frac{1}{17}$	15	29	26	70	10	$\frac{1}{7}$	16	16	8	40	2	$\frac{1}{20}$	26	21	23	70	11	$\frac{1}{7}$	320	31
8-in mortar.	15	10	15	40	...	...	26	23	11	60	14	$\frac{1}{4}$	14	11	15	40	...	...	16	12	12	40	8	$\frac{1}{5}$	180	22
10-in. how.	14	13	3	30	...	...	14	26	20	60	16	$\frac{1}{4}$	18	22	20	60	6	$\frac{1}{10}$	4	14	12	30	10	$\frac{1}{3}$	180	32
	148	136	143	427	20	$\frac{1}{21}$	63	92	65	220	46	$\frac{1}{5}$	136	85	89	310	12	$\frac{1}{26}$	70	64	76	210	38	$\frac{2}{11}$	1167	116

At 400 yards, at 10°.	At 400 yards, at 15°.	At 500 yards, at 10°	At 500 yards, at 15°.
Of 427 rounds fired, 136 took effect, being less than $\frac{1}{3}$. Of the same number of rounds (427) fired, only 20 struck the wall 12 ft. from top, being less than $\frac{1}{21}$.	Of 220 rounds fired, 92 took effect on wall, being more than $\frac{2}{5}$. Of the same number of rounds (220) fired, 46 struck the wall 12 ft. from top, being more than $\frac{1}{5}$.	Of 310 rounds fired, 85 took effect on wall, being rather less than $\frac{2}{7}$. Of the same number of rounds (310) fired, only 12 struck the wall 12 ft. from top, being more than $\frac{1}{26}$.	Of 210 rounds fired, 64 took effect on wall, being rather more than $\frac{2}{7}$. Of the same number of rounds (210) fired, 38 struck the wall 12 ft. from top, being rather less than $\frac{2}{11}$.

5. By the comparison of fire from 400 and from 500 yds. in the foregoing table, it is found that the former range is preferable to the latter, and with regard to the best angle of elevation to be used 15° has greatly the advantage over 10° at 400 yds., and is something better than the smaller angle at 500 yds., but with respect to the number of shot striking 12 ft. from the top, the angle of 15° is at both ranges far superior in effect.

It ought also to be considered with respect to probable penetration with the small charges necessarily used, but as the experiment has only been made on a wall of lightly rammed earth, it is difficult to calculate anything like an effect. It is a fair presumption, however, that the action of such powerful projectiles as 68-pr. shot, assisted by 10-in. shells filled with powder, would very possibly succeed in breaking down the brick wall in question.

6. On the whole therefore it appears that 68-pr. carronades and 10-in. howitzers placed in battery at 400 yds., and fired with 15° of elevation, afford the greatest hopes of success, and by the preceding table there is just reason to expect, that from a continuance of fire without change, about half the practice would be successful.

It is in consequence submitted to His Grace the Master-General, whether these results do not merit a more definitive investigation of the experiment, by trying the fire against a real wall, disposed according to the profile of Carnot's system.

(*The draught is not signed, but is in the handwriting of the late Sir Alexander Dickson, R.A.*)

APPENDIX. No. 2.

REPORT ON THE PRACTICE AGAINST A CARNOT WALL, CARRIED ON AT WOOLWICH, BY ORDER OF HIS GRACE THE MASTER-GENERAL, IN AUGUST, 1824.

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1. His Grace the Master-General having considered it possible that the walls used in the new system of fortification recommended by Carnot, and carried into execution in late years in different countries might be breached at considerable distances by fire at high angles, desired in the year 1822, that a profile in earth might be prepared for trial, placing a screen of the proper height in lieu of a wall.

The experiment tried at Woolwich, in August, 1822, proved that this fire could reach very low down the wall.

It was doubtful, however, whether the projectile would breach the wall at considerable distances, say four or five hundred yards, considering the small quantity of powder, which it was necessary to use.

His Grace the Master-General then determined that he would continue the experiment, and had a wall constructed of the usual dimensions, in the summer of 1823. It was 21 ft. high, and 22 ft. long, of the regular thickness of 6 ft. at top, and of 7 ft. at bottom as recommended by Carnot, and had one loop-hole in the usual recess. It was further strengthened by a buttress of 4 ft. square at each end, so that the total length of the wall, including the buttresses, was 30 ft. at bottom and 28 ft. at top; the buttresses giving it a considerable additional strength beyond the usual wall of Carnot's system.

2. The wall was carefully built, and well cemented. An earthen counterguard, of the regular thickness, and of equal height with the wall, was thrown up before it: the crest of the counterguard being twenty yards from the top of the wall.

A mound of earth, representing the rampart of a bastion, was thrown up behind the wall, and was continued at the regular slope of 45 degrees, till its height was 4 ft. above that of the wall, but this rampart being 8 ft. lower than the real rampart of a bastion would have been, was on that account of less use in serving as a correction to the elevation of the ordnance.

Two batteries were constructed against the wall and opened their fire, on the 5th August, 1824.

They consisted of the following pieces of ordnance:—

Eight 68-pr. carronades		at 500 yds.,	from the crest of the counterguard.
Three 8-in. iron howitzers		at 400 ,,	,, ,,
Three 10-in.	do	400 ,,	,, ,,

One hundred rounds per piece were fired in about six hours; the howitzers firing live shells filled with powder, the carronades firing solid shot.

On examining the wall there was a practicable breach of 14 ft. wide, and the buttresses were much injured.

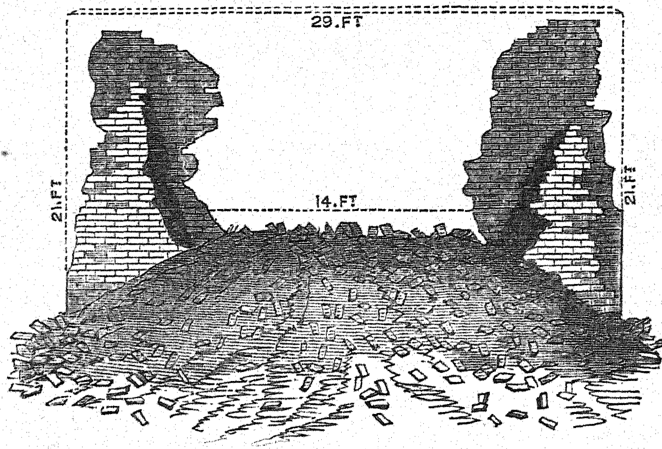


Fig. 1.

Front view of the wall shewing the effect of the first and second day's fire.

The splinters of the shells being inconvenient to the men in the 400 yds. battery, the bursting powder of the shells was considerably reduced.

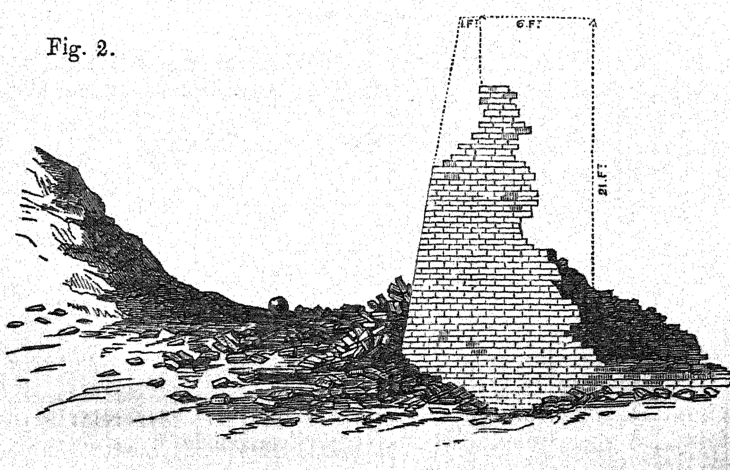
3. On the 6th of August the firing recommenced from

Eight 68-pr. carronades		at 500 yds.
Two 8-in. iron howitzers		400 „
Four 10-in.	do	400 „

The fire of these pieces was intended to be directed towards the more effectual opening of the breach and the more complete destruction of the buttresses.

Fifty rounds per piece were fired in two hours, when the breach was examined and found to be complete in every respect, and the buttresses to be in the ruinous state more clearly shown by the darker shade of fig. 1.

Fig. 2.

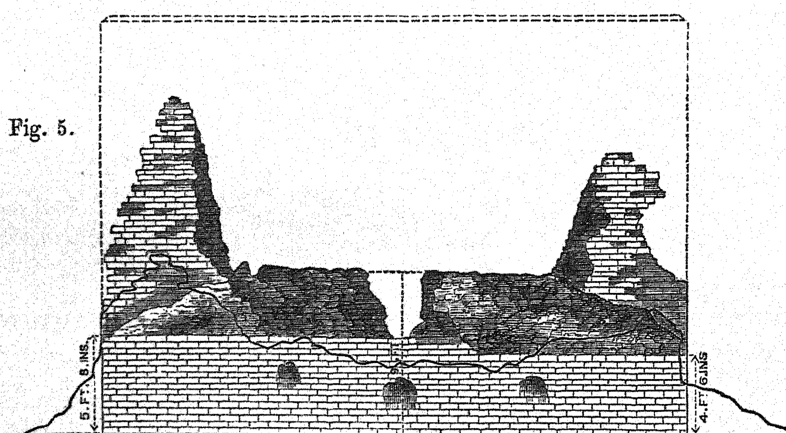


Side view of the wall after the second day's fire.

On the 5th and 6th August, two of the 8-inch iron howitzers, two of the 10-inch iron howitzers, and four carronades, had been placed on high traversing platforms, so as to raise them nearly to the natural level of the country according to Carnot's system. But His Grace the Master-General, who examined the breach at this period, having given directions that all the ordnance should be placed on common platforms, the use of the traversing platforms was discontinued. It had previously been observable, that no advantage or superior accuracy of fire attended raising the guns, which was merely done that the experiment might more scrupulously follow Carnot's system, with respect to the relative levels of the wall, counterguard, and the natural level of the country.

His Grace also ordered that the rubbish should be cleared away, both from the front and rear of the breach. This was accordingly done, when the wall was found to be 5 ft. in perpendicular height in front, with a rounding of rubbish of about 2½ or 3 ft. on the top; and to be about 8½ or 9 ft. in height towards the rear, or *chemin de ronde* as will be clearly shown by fig. 5.

Fig. 5.



Front view of the wall when the rubbish was cleared away from the breach after the second day's fire.

4. On the 11th of August the batteries recommenced their fire from eight 68-pr. carronades 500 yds., and six 10-in. iron howitzers 400 yds., when eighty-five rounds from each of the howitzers, and one hundred from each of the carronades were fired in 3½ hours, by which time the wall and buttresses were one mass of ruin, and the *chemin de ronde* was obliterated, as is more clearly shown in figs. 3 and 4.

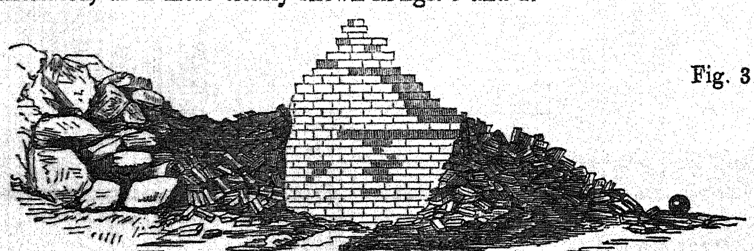
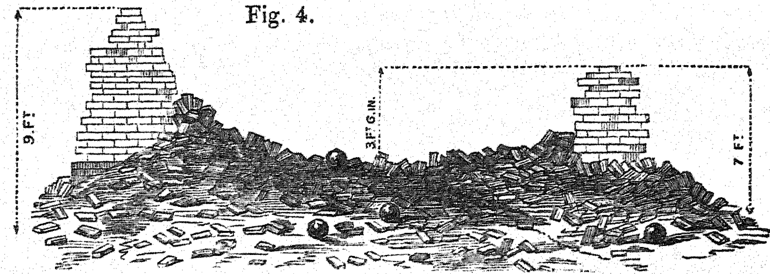


Fig. 3.

Side view of the wall after the third day's fire.

Fig. 4.



Front view of the wall after the third and last day's fire.

The power of artillery to destroy Carnot's wall has been therefore clearly established, the guns having received no aid as to charge, direction, or elevation, beyond what real service would afford, and the shells having in some measure been less efficacious than they really would have been, from the circumstance of so much powder having been taken out of them after two hours of the first day's fire (on account of the splinters reaching the batteries), that a very considerable number of the shells did not explode.

5. From careful observation it appeared that about $\frac{1}{4}$th of the shells and $\frac{1}{5}$th of the shot struck the wall,* many of both, which but just missed it, would have been efficacious, had the wall been longer.

The increased rapidity of the fire is also observable, that of the third day being nearly double that of the first day, although the reduction in the height of the wall from 21 ft. to 5 ft. rendered the operation obviously more difficult.

A general view of the counterguard is also added in fig. 8, to show the appearance of the effect of the shells on its superior slope.†

(Signed)

R. DOUGLAS,

Director-General, F. T.

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* Sir Howard Douglas gives the following more precise statement, which has been adopted in the text.

	Took effect on wall.		Counterguard.		Bastion.	
	Shot.	Shells.	Shot.	Shells.	Shot.	Shells.
1st day	180	158	192	190	not observable.	
2nd day......	36	58	128	111	92	65
3rd day	73	86	204	176	235	216
	289	302	524	477	327	281

Weight of iron fired, 112 tons, 11 cwt., 64 lbs. Sir Howard Douglas makes it rather more, having taken the carronade shot as weighing 68 lbs. instead of $66\frac{1}{2}$ lbs.—J. H. L.

† It has not been thought necessary to reproduce this view.

APPENDIX. No. 3.

REPORT

OF THE

ORDNANCE SELECT COMMITTEE.

No. 1988, dated December 2, 1861.

ON THE EFFICIENCY OF ARMSTRONG GUNS EMPLOYED IN RICOCHET FIRE.

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1. THE Committee have the honor to submit the following Report of Experiments made under instructions received in June to test the efficiency of Armstrong guns when employed in enfilading a battery, and the distance at which the fire is most destructive and certain. The work in Plumstead Marshes was put in repair for this trial. It consists of a single face about 340 ft. long, with two flanks. It is divided unequally by four traverses, and further derives essential protection from a screen or bonnette of earth 10 ft. high and 30 ft. long, at the angle of the nearest flank. Ground platforms were laid for four guns, and two mortars (the latter were unoccupied); iron traversing platforms for two guns; wooden traversing platforms for two guns; and there were two guns on naval carriages not on any platforms; in all ten guns mounted. In addition to which, on the last occasion of fire, a second row of three guns was formed 50 ft. in rear of the proper armament, leading up to a small field magazine which it was desired to strike.

2. After some preliminary practice to ascertain the ranges due to reduced charges and high elevations, the Committee proceeded on the 30th October, and 6th November, to ricochet the work; 950 yds. from the nearer angle, or 1000 yds. from the centre, was fixed on as a proper distance for the battery, being beyond the risk of much annoyance from an enemy's riflemen. The guns in battery were—

(1) Smooth-bored 32-pr. of 25c.
(2) „ 8-in. of 62c.
(3) Armstrong 40-pr.
(4) „ 20-pr.
(5) „ 12-pr.

The work fired at not being visible from the battery, owing to an intervening parapet, pickets were set up in proper alignment on this parapet at 340 yds. in advance, to aid the laying of the guns, and a non-commissioned officer was posted near them, under cover, to signal the apparent result of each shot.

The following is an abstract of the practice:—

Date.	No.	Charge.	Elevation.	Effects.	First Grazes.
1861.		oz.	° ′	§ 3. ARMSTRONG 40-pr.	yds.
Oct. 30.	1	24	8 0	Knocked off about 16 in. of the muzzle of an 18-pr. gun, which had been cracked by a former blow	1002
	2	—	—	Lodged in the parapet	990
	3	—	—	do do	995
	4	—	—	do do	1012
	5	—	—	Slightly grazed the muzzle of a gun, and proceeded over the work	1000
	6	—	—	Lodged in the parapet	990
	7	—	—	In the work; grazed the front of a wooden platform without occasioning serious splinters	1015
	8	—	—	Grazed a traversing platform, and lodged in a traverse	995
	9	—	—	Into the parapet	980
Nov. 6	10	—	8 10	Into the further flank	960
	11	—	8 0	Struck a traverse	1050
	13	—	7 45	Went through the cheeks of a carriage, and struck a wooden platform causing numerous splinters. The carriage was old	1020
	14	—	7 30	In the work	968
	15	—	7 30	Struck the parapet	?
	16	—	7 30	In the work	980
	17	—	7 30	Caught by the bonnette about	960
	18	—	7 30	Struck outside	930
	19	—	7 30	Struck the parapet	970
	20	—	7 30	Struck outside about	930
	21	—	7 30	Caught by the bonnette	960
	22	—	7 30	Grazed the rear of the bonnette, and skimmed along the whole length of the work without rising more than a foot or two, burying itself at last in the further flank	960
				§ 4. ARMSTRONG 20-pr.	
Oct. 30	1	12	8 30	Short	—
	2	—	8 45	do	—
	3	—	9 0	do	—
	4	—	9 15	Caught by the bonnette	970
	5	—	9 30	Short	844
	6	—	9 45	do	917
	7	—	9 50	Caught by the bonnette	970
	8	—	9 55	do do	970
	9	—	9 55	Short	900
	10	—	9 55	Caught by the bonnette	970
Nov. 11	11	14	8 0	Short	900
	12	—	8 10	do	910
	13	—	8 0	Into the nearer flank	940
	14	—	8 0	Struck the top of the bonnette	970
	15	—	8 0	Into the bonnette	960
	16	—	8 0	Short	—
	17	—	8 0	Rather short	930
	18	—	8 0	Into the bonnette	950
	19	—	8 0	Short	912
	20	—	8 0	Struck a traverse, and did not rise, but turned over where it fell	965
	21	—	8 0	Struck a traverse	964
	22	—	8 0	Into the bonnette	950

Date.	No.	Charge.	Elevation.	Effects.	First Grazes.
1861.		oz.	° ′	§ 5. ARMSTRONG 12-pr.	yds.
Oct. 30	1	7	8 0	Struck short, and ricocheted into the bonnette	850
	2	—	8 15	Struck the parapet near the 1st traverse	970
	3	—	8 15	Caught by the bonnette	960
	4	—	8 25	Passed under an iron traversing platform, and was stopped by traverse 2	990
	5	—	8 25	Struck traverse 2	990
	6	—	8 25	Struck traverse 3	1018
	7	—	8 25	Short	900
	8	—	8 25	Caught by the bonnette	960
	9	—	8 25	Rather short	920
	10	—	8 25	Caught by the bonnette	960
Nov. 6	11	8	7 0	Grazed a gun carriage and the iron traversing platform it was on; buried in traverse 2	990
	12	—	6 50	Rather short .... about	920
	13	—	6 55	Struck short, and ricocheted over	—
	14	—	7 0	Short	—
	15	—	7 0	do	—
	16	—	7 10	Struck short, and ricocheted into the further flank	990
	17	—	7 10	Rather short .... about	930
	18	—	7 10	Struck short, and ricocheted over .... about	843
	19	—	7 10	Caught by the bonnette .... about	960
	20	—	7 10	Struck short	910
	21	—	7 10	Caught by the bonnette	960
	22	—	7 10	Struck the nearer flank	936
				§ 6. 8-in. GUN OF 62 cwt.	
Oct. 30	1–7	20	—	All short...	—
	8	—	12¾ 0	Into traverse at...	995
	9	24	12¾ 0	Short	912
	10	—	13 0	Over into the butt beyond	1100
Nov. 6	11	32	7 0	Short .... about	800
	12	—	7¼ 0	Short; ricocheted into the further flank	900
	13	—	7½ 0	Short; the second graze was in the work, and the third into the further flank	906
	14	—	8 0	Rather short, and ricocheted clear over the work into the butt	933
	15	—	9 0	Clear over the work into the butt	1100
	16	—	8½ 0	In the work beyond the furthest traverse.........	1050
	17	—	8½ 0	Into the further flank	1060
	18	—	8½ 0	Clear over the work	—
	19	—	8½ 0	Rather short; grazes not recorded	1020
	20	—	8½ 0	Struck the parapet at 1010 yds., then ricocheted against the side of a wooden traversing platform at 1030 yds., and fell beside it making a small indentation only..................................	1030
	21	—	8½ 0	Clear over	—
	22	—	8½ 0	In the work	940
	23	—	8½ 0	Clear over	—
	24	—	8½ 0	In the work	1050
	25	—	8½ 0	Near the same place as the last	1050
				§ 7. 32-pr. of 25 cwt.	
Oct. 30	1	22	8 0	Rather short	—
	2	—	8 0	Over	—
	3	—	8 0	do	—
	4	—	8 0	do	—
	5	—	7½ 0	Rather short	916

Date.	No.	Charge.	Elevation.	Effects.	First Grazes.
1861.		oz.	° ′	32-pr. of 25 cwt.—*Continued.*	yds.
Oct. 30	6	22	$7\frac{3}{4}$ 0	Into parapet	1002
	7	—	$7\frac{3}{4}$ 0	Over	—
	8	—	$7\frac{3}{4}$ 0	Into the ditch of the work at about	1000
	9	—	$7\frac{3}{4}$ 0	Struck the bonnette high	960
	10	—	$7\frac{3}{4}$ 0	Into the work	1010
Nov. 6	11	—	$7\frac{3}{4}$ 0	Rather short	910
	12	—	$7\frac{3}{4}$ 0	Struck a wooden platform without causing serious splinters, and into traverse 3	1015
	13	—	$7\frac{3}{4}$ 0	Short, struck the bonnette on second graze	—
	14	—	$7\frac{3}{4}$ 0	Into the work	995
	15	—	$7\frac{3}{4}$ 0	do	1008
	16	—	$7\frac{3}{4}$ 0	Went clear over the butt about	1160
	17	—	$7\frac{3}{4}$ 0	Struck the butt high about	1100
	18	—	$7\frac{3}{4}$ 0	Struck the butt about	1055
	19	—	$7\frac{3}{4}$ 0	Passed through an iron gabion and buried itself in the cheek of an embrasure	1025
	20	—	$7\frac{3}{4}$ 0	Into the work behind traverse 3	1010
	21	—	$7\frac{3}{4}$ 0	Grazed the rear of traverse 2, carrying away 2 gabions	990
	22	—	$7\frac{3}{4}$ 0	Into traverse 3	1020

8. The results of the foregoing practice may be stated generally as follows:—

	Armstrong.				Smooth-bore.		
	40-pr.	20-pr.	12-pr.	Total.	8-inch.	32-pr.	Total.
Shots which fell in the work, or on the parapet	17	2	5	24	7	10	17
Shots caught by the bonnette which would have otherwise entered the work	2	8	6	16	0	1	1
Short	2	12	11	25	13	3	16
Over	0	0	0	0	2	8	10

9. It will be seen that very little material was struck, there was consequently little opportunity of judging of the effect of Armstrong projectiles in dismounting ordnance. It has however been ascertained that the initial velocity of the 12-pr. shell is as follows:—

With charge 6 oz. 500 ft. per second.
„ 8 oz. 620 ft. „
„ 10 oz. 732 ft. „

It is probable that these velocities will be very near the truth for charges of the other natures bearing the same proportion to the weight of the shot, namely, for the 40-pr.—20 oz., 26·6 oz., and 33·8 oz.; for the 20-pr.—10·5 oz., 14·0 oz., and 17·5 oz; and their mechanical effects can therefore be easily compared with those of smooth-bored projectiles if we also ascertain the

velocity of the latter. This has not at present been done for the low charges used in ricochet fire,* but by calculation the initial velocity of a 32-pr. shot, with 22 oz. of powder, as fired on this occasion, is about 715 ft. per second; being nearly 100 ft. greater than that of the 12-pr. and 20-pr., and 120 ft. greater than that of the 40-pr. The elongated projectiles preserve their velocity rather better than the round shot; but on the whole, although it appears sufficiently great to produce destructive effect on the Artillery material they strike, it must be less than that of the round shot, and consequently their mechanical effect less also: on the other hand the larger bursting charges of elongated shells will make these much more destructive to traverses and solid obstacles, as well as to troops.

10. The present practice has fully satisfied the Committee that Armstrong projectiles may be fired with greatly reduced charges, so as to have a high descending angle, and still retain precision of direction and uniformity of range. This adapts them well for silencing guns covered by traverses, or for breaching caponnières and sunken defences; but they are not so well adapted as round shot for what is commonly intended by ricochet fire, namely, to proceed through a work by short bounds, making more than one graze in it. The second graze is almost invariably too far distant from the first to be in any way relied on; it is however tolerably regular both in direction and distance.

The following Table contains the observed first and second grazes of a part of the practice. In some instances the second graze was not traced.

Comparison of 1st and 2nd grazes of Armstrong projectiles.

Gun.	Charge.	Elevation.	No. of round.	Mean range. 1st graze.	Mean range. 2nd graze.	Diff. 1 – 2	Deflection. 1st graze R	Deflection. 2nd graze R	Soil.
	oz.	°		yds.	yds.	yds.	yds.	yds.	
12-pr.	6	7	2	765	1290	525	—	23	Good turf
do	—	10	2	937	1331	394	—	75	do
do	8	5	3	729	1513	784	—	63	do
20-pr.	16	5	3	744	1536	792	—	115	do
do	—	7	5	1009	1600	591	—	65	do
do	18	5	3	828	1405	577	—	47	do
do	—	7	4	1112	1795	683	—	71	do
do	20	7	5	1195	2188	993	2·4	50	Wet sand
do	—	10	5	1650	2435	785	6·7	61	do
40-pr.	32	5	5	883	1683	800	1·1	47	do
do	—	7	5	1173	2286	1013	2·7	80	do
do	36	5	5	1004	2058	1054	1·7	38	do
do	—	7	5	1306	2422	1116	2·7	60	do
do	40	5	5	1083	1933	850	1·7	86	do
do	—	7	5	1448	2626	1178	3·7	166	do

11. Two exceptional grazes occurred in the practice, both of which would have been very destructive inside a work. A 20-pr. shot fired at 5° with 18 oz. charge, struck the ground at 798 yds., and cut off the top of the

* See Table III. for results obtained since the date of this Report.

long grass in a continuous line for 19 yds., the ground here dipped a little, but the trace was distinguishable further on, shewing that it could not have risen so much as a foot for 120 yds. A 40-pr. shot fired at $7\frac{1}{2}^\circ$, charge 24 oz., struck the ground at 980 yds., and skimmed along until stopped by the shoulder of the battery at 1060 yds., not rising above 2 or 3 ft. It will be seen however by the distance of the second graze from the first as given in column 7, that with these rare exceptions, the effect of each shot will be confined to the portions of the descending and rising branches of the curve comprised between the ordinary height of a parapet and the ground—a distance of 100 to 150 ft. according to the angle. There is scarcely any chance of shot which fall short, getting into the work on second graze, a thing which frequently happens with round shot and shells.

12. The Committee do not consider it necessary to expend more ammunition in endeavouring to strike the half-sunken field magazine, which has not yet been struck, or to obtain more direct evidence of the effect of a blow on guns and gun carriages; they recommend that the use of the 12-pr., 20-pr., and 40-pr. Armstrong guns with reduced charges at high angles, be reduced to practice, and recognized as an occasional employment of those guns, and that the Commanding Officers, Royal Artillery, receive instructions to keep a careful record of the results of all shots which take effect on material as well as of the actual first grazes for given charges and elevations, to verify the annexed table. They would also suggest that orders be given to the P. S. S. to issue fresh (unserviceable) carriages instead of some of those now in the work, which are too much shattered to furnish any longer a fair illustration of the effects of shot.

(Signed) J. St GEORGE,
President O. S. C.

Table VIII.

GIVING THE APPROXIMATE ELEVATIONS NECESSARY TO PITCH AN ARMSTRONG SHOT OR SHELL INTO A WORK AT THE DISTANCES SPECIFIED, AND WITH THE CHARGES GIVEN.

Distance of object.	L. S. 12-pr.			L. S. 20-pr.			L. S. 40-pr.			
	Elevation for			Elevation for			Elevation for			
	oz. 6	oz. 8	oz. 10	oz. 14	oz. 16	oz. 18	oz. 24	oz. 28	oz. 32	oz. 36
yds.	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
500	5 6	...	...	...	...	...	...	...	...	...
600	5 54	...	...	...	...	...	...	...	...	...
700	6 42	4 15	...	6 20	4 50	...	5 30	...	...	...
800	8 0	5 10	...	7 4	5 30	4 50	6 15	5 20	...	...
900	9 30	6 5	4 40	7 46	6 13	5 30	7 8	6 5	5 5	...
1000	...	6 58	5 20	8 30	6 56	6 10	7 55	6 45	5 45	5 0
1100	...	8 6	6 4	9 10	7 40	6 50	8 35	7 30	6 30	5 40
1200	...	9 20	6 46	9 50	8 25	7 40	9 25	8 12	7 10	6 20
1300	...	...	7 40	...	9 10	8 23	...	9 0	8 0	7 0
1400	...	...	8 40	...	10 0	9 10	...	9 46	8 45	7 40
1500	...	...	9 40	...	...	9 55	...	...	9 30	8 25
1600	...	...	...	...	...	...	...	...	...	9 15

TABLE IX.

APPROXIMATE ANGLES OF ELEVATION AND TIMES OF FLIGHT DUE TO SHORT DISTANCES WHEN THE ANGLE OF DESCENT IS REQUIRED TO BE NOT LESS THAN 10°.

Elevation.	20-pr. 21·5 lbs.		40-pr. 40·5 lbs.		70-pr. 69·62 lbs.		7-in. howitzer or 110-pr. gun. 103·87 lbs.		7-inch mortar. 87·56 lbs.	
°	yds.	sec.	yds.	sec.	yds.	sec.	yds.	sec.	yds.	sec.
	Charges all in the proportion 0·0211 P.									
8	410	3·7	520	4·1	445	3·7	480	4·2	520	4·0
9	435	4·1	560	4·6	500	4·3	540	4·6	570	4·7
10	460	4·4	610	5·2	550	4·8	600	5·0	620	5·5
11	480	4·7	640	5·5	600	5·3	665	5·4	660	6·1
12	500	5·1	680	6·1	650	5·7	730	5·8	705	6·8
13	520	5·4	715	6·7	690	6·2	780	6·4	750	7·5
14	535	5·6	750	7·1	740	6·7	830	7·0	790	7·9
15	555	5·9	780	7·5	780	7·1	890	7·6	830	8·3
	Charges all in the proportion 0·0236 P.									
8	480	4·2	600	4·4	540	4·2	560	4·4	560	4·3
9	520	4·7	655	4·9	600	4·7	620	4·9	615	4·8
10	560	5·2	710	5·3	660	5·2	680	5·4	690	5·4
11	595	5·6	770	5·9	725	5·7	740	5·9	745	5·9
12	625	5·9	830	6·4	790	6·2	810	6·4	800	6·3
13	660	6·3	890	6·9	850	6·7	870	6·9	860	6·9
14	680	6·6	940	7·2	910	7·3	930	7·4	910	7·4
15	705	7·0	1000	7·7	970	7·9	990	8·0	960	7·9

The above charges are respectively,—

	lbs.	oz.	dr.		lbs.	oz.	dr.
For the 20-pr.......	0	7	8	and	0	8	9
„ 40-pr.......	0	14	0	„	1	0	0
„ 70-pr.......	1	7	6	„	1	10	12
„ 7-in. how. or 110-pr. gun	2	3	8	„	2	8	9
„ 7-in. mortar	1	14	1	„	2	2	6

In practice it will be sufficient to take them to the nearest half-ounce.

NOTE.—In the fourth column of Table II. p. 233, the quantities are to be divided by 2, g having been inadvertently used instead of $2g$.

ACCOUNT

OF

EXPERIMENT OF 29TH DECEMBER, 1862, CONTINUED, ON CAPTAIN INGLIS'S SECOND SHIELD, AT SHOEBURYNESS, 3RD MARCH, 1863.

[CONTRIBUTED BY CAPTAIN E. J. BRUCE, R.A.]

[For description of Shield, see page 224 *antè*].

The following guns were used in the experiment:—

One 300-pr. Armstrong muzzle-loading shunt gun. Calibre, 9·20″. Weight, 11 tons. 15 cwt. 2 qrs.
One 100-pr. Armstrong muzzle-loading smooth-bore gun.
One 130-pr.* Whitworth rifled gun.
One 7-in. Lynall Thomas rifled gun. Weight, 149 cwt. 3 qrs. 14 lbs.

Number of round.	Number on target, 15.	Nature of ordnance.	Projectile. Nature.	Weight in lbs.	Form.	Length in inches.	Diameter.	Charge in lbs.	Length of charge in inches.	Elevation.	Range in yds.	Deflection.	Effects. Depth of indent in inches.	Diameter of indent in inches.	Velocity at 563 feet.	Remarks.
1	532	130-pr Whitworth rifled gun.	S.S.†	148	F.B.	17·3	...	25	25·5	15′	200	nil	...	9·5 × 7·3	1239·9	Struck 3 and 4 planks 3′ 4″ from the bottom; 2″ of indent was on plank No. 3; the bulge on plank No. 3 measured 1·3″ in depth, but the depth of indent on No. 4 could not be taken, as part of the shot remained in the indent; the edge of plank No. 3 was cracked in the bulge for a length of 1·5″; a narrow crack on plank No. 4 at 1′5″ from the point of impact extending from a bolt-hole to the edge of the plank. At the back, slight bulge of ·4″ of horizontal plank at seat of blow; lead sheeting, at left side of embrasure, pressed out; plank below the one struck gaping ·5″ from front plank at side of embrasure; vertical frame piece, to left of embrasure, slightly curved back.
2	533	100-pr smooth bore gun.	S.S.‡	113	spherical	...	9·16	,,	13·75	16	,,	,,	2·4	11·3 × 10·4	1461·8	Struck at 2′ 2″ from the bottom of the target, and 5·5″ from the side of the plank; a bolt 8·5″ from the point of impact started ·3″; the edge of No. 4 plank was bulged 2″ × 1·5″, and the edge of the plank was cracked on the bulge for a length of 5″. At the back, the second through bolt from the top of the left row, distant about 3′ from point of impact, was broken; the lead washers of No. 4 through bolt, from the top of the same row, squeezed and broken, and angle iron bulged out ·5″; the lower horizontal plank, about 1′ beneath the blow, was cracked through vertically; the left vertical frame piece was slightly curved, and angle iron at top set back from it. Major diameter of shot after firing 12·2″.

* Hitherto recorded as 120-pr. † Solid shot, Frith's steel.
‡ Solid shot, wrought-iron.

Number of round.	Number on target, 15.	Nature of ordnance.	Projectile.					Charge in lbs.	Length of charge in inches.	Elevation.	Range in yds.	Deflection.	Effects.		Velocity.	Remarks.
			Nature.	Weight in lbs.	Form.	Length in inches.	Diameter.						Depth of indent in inches.	Diameter of indent in inches.		
3	534	300-pr	H.*	230	C.†	19·	...	45	18·5	20′	200	2′ R	1·45	10·0 × 9·5	1400·6	Struck No. 3 plank 1′ 9″ from the bottom; the plank was cracked across its width through the indent; the crack made by round No. 1 extended to a bolt-hole, and the plank was cracked completely through its width and thickness at 1′ 5·5″ from the top, the crack being ·4″ wide on the front, and having extended from an old crack, 4″ long, made by the previous day's firing; the plank was driven in 1·8″ for 3′ 6″ from the bottom; the bottom bolt of the plank started ·2″, and the two bolts next above were driven in ·2″ and ·4″. At the back, a through bolt, just below embrasure, broken off; vertical frame piece, or "upright of frame," bent considerably at seat of blow; gaping of horizontal planks from front planks, at left side of embrasure, increased now to an inch; horizontal frame piece, or cross stay, at bottom curved back considerably; a through bolt (masked by the above frame piece) broken, and its head brought up pressing against the frame piece; washers of No. 2 through bolt from the top of right row, squeezed up; bottom through bolt, right side, loose, being broken in front; vertical frame piece, right of all, slightly curved; and a partial crack (former day's practice) now continued through the thickness of iron.
4	535	7-in.‡	W.§	150	cylindrical. R.E.	16·5	...	25	22·5	20	„	nil.	1·8	8 × 7·5	1217·9	Struck No. 1 plank 4′ 7″ from the bottom, and 5″ from the side; plank driven in 1·8″ at point of impact, and the edge of plank No. 2 bulged 1″ in a length of 10″; the plank cracked diagonally across its width through a bolt-hole at 1′ 2″ above the point of impact; also from a bolt-hole to the right side of the plank at 1′ 5·5″ below the point of impact; a crack 15″ long also extended from the left side of the plank at 2′ 7″ below the point of impact. The shot set up 6·5″.

* Hollow-headed cast-iron shot. † Cylindrical F.E., with hollow hemispherical head.

Number of round.	Number on target, 15.	Nature of ordnance.	Projectile. Nature.	Projectile. Weight in lbs.	Projectile. Form.	Projectile. Length in inches.	Projectile. Diameter.	Charge in lbs.	Length of charge in inches.	Elevation.	Range in yds.	Deflection.	Effects. Depth of indent in inches.	Effects. Diameter of indent in inches.	Velocity.	Remarks.
5	536	130-pr Whitworth.	S.S.*	150	F.E.	17·5	...	25	25·5	15′	200	nil.	...	13 × 11	1241·0	Struck the plate below embrasure 1′ 8″ from the top, and 10″ from the left side, which was driven in ·8″ on the right side, and 1·1″ on left side; the shot broke up and a portion remained in indent, the depth of which could therefore not be taken; the bottom bolt started 1″, and a crack, made by previous firing, on plank No. 2, opened to ·3″. At the back, a through bolt 2′ 6″ from point of impact driven out; whole of bottom of embrasure set back, opening between front and rear planks ·5″; a slight irregular starred crack on lower horizontal plank; lower horizontal frame piece rather more bulged back.
6	537	300-pr	S.C.†	307	cylindrical. R. E.	18·5	...	45	18·5	25	„	4′R	2 on plank 3, and 1·3 on plank 4.	12·5 × 12	1228·4	Struck at the junction of planks 3 and 4, 3′ 2″ from the top of the target; a portion of the shot remained in plank 3; the cracks at the top and bottom of this plank made by round No. 3 much enlarged, and now measure ·6″ and ·9″ in width. At the back, a through bolt (the second from the top of the third row from left) broken; through bolt, top of second row from left, much squeezed up; vertical frame piece considerably bulged (now 1·2″); horizontal planks 2, 3, and 4 from top also bulged; 3 and 4 horizontal planks opening out from front planks 1″ at left side of embrasure.
7	...	7-in gun.	S.S.‡	138	R.E.	14·5	...	27·5	25·	18	„	„	...	...	...	The gun burst, and the shot did not strike the target.

* Solid shot, Frith's steel. † Solid cast-iron shot. ‡ Solid steel shot.

REPORT

OF

AN EXPERIMENT CARRIED ON BY THE SPECIAL COMMITTEE ON IRON, AT SHOEBURYNESS, 17TH MARCH, 1863, TO TEST THREE ROLLED ARMOUR PLATES, SUPPLIED BY MESSRS JOHN BROWN AND CO., OF SHEFFIELD.

[CONTRIBUTED BY CAPTAIN E. J. BRUCE, R.A.]

The plates were of the following dimensions and weights:—

	cwt.	qrs.	lbs.
No. 1.—13′ 4″ × 3′ 6·75″ × 5·5″ …………………	93	1	6
2.—12′ 2·75″ × 3′ 7·75″ × 6·5″ …………………	103	2	0
3.—11′ 9·25″ × 3′ 8·75″ × 7·5″ …………………	116	2	10

They were secured by 2·5″ conical-headed bolts, with double nuts, to the frame of Mr Samuda's target (2·5″ thick) and were backed by timber for one-half their length; the 5·5″ plate by 9″, the 6·5″ plate by 8″, and the 7·5″ plate by 7″, so that the front of the target presented a plane surface; india-rubber washers were placed under the bolt-heads.

The plates were divided into compartments by seven vertical lines, numbered from 1 to 7, and by three horizontal lines; the backed portion of the plates extended from 1 to 4, and the unbacked portion from 4 to 7.

The guns used in the experiment were:—

One 300-pr. Armstrong muzzle-loading shunt gun.
One Lynall Thomas's 9-in. gun.
One Whitworth 130-pr. muzzle loading rifled gun.
One 110-pr. Armstrong breech-loading rifled gun.
One 68-pr. smooth-bore 95 cwt. gun.

Number of round.	Photographic No.	Nature of ordnance.	Projectile.				Bursting charge of shells.	Charge in lbs.	Elevation.	Range in yds.	Deflection.	Effects.		Remaining velocity.	Remarks.
			Nature.	Weight.	Form.	Length.						Depth of indent in inches.	Diameter of indent in inches.		
				lbs. oz		in.	lbs. oz.		′		′				
1	542	68-pr.	Cast-iron solid shot.	65 14	Spherical.	…	…	16	23	200	nil.	2·	9·7 × 9	…	Struck the 5·5″ plate 9″ to the right of 3 vertical and 11″ below 2 horizontal; the plate driven in at the bottom ·4″ in a length of 2′.
2	543	,,	,,	,,	,,	…	…	,,	,,	,,	,,	1·6	9·5 × 9	…	Struck the 7·5″ plate 3″ to the left of 5 vertical and 8″ below 2 horizontal.
3	544	,,	,,	,,	,,	…	…	,,	,,	,,	,,	,,	9·7 × 9·5	…	Struck the 6·5″ plate 6″ to the left of 4 vertical and 3″ below 2 horizontal. At the back, after these three rounds, one rivet-head off the top right of target, and the lead and india-rubber washers of two through-bolts squeezed up.

Number of round.	Photographic No.	Nature of ordnance.	Projectile. Nature.	Projectile. Weight.	Projectile. Form.	Projectile. Length.	Bursting charge of shells.	Charge in lbs.	Elevation.	Range in yds.	Deflection.	Effects. Depth of indent in inches.	Effects. Diameter of indent in inches.	Velocity at 508 feet.	Remarks.
				lbs. oz		in.	lbs. oz.		′		′				
4	545	110-pr Armstrong gun.	Cast-iron solid shot.	65 15	Cylindrical.	...	...	16	15	200	9 R	1·9	8·	...	Struck the 5·5″ plate 4″ to the right of 6 vertical and 3·5″ above 2 horizontal; a bolt, 14″ from impact, started ·3″, and a narrow crack, 8″ long, on indent.
5	546	„	„	„	„	...	...	„	„	„	„	2·05	8·5 × 9·5	...	Struck the 6·5″ plate 3″ to the right of 6 vertical and 5″ above 2 horizontal.
6	547	„	„	„	„	...	...	„	„	„	„	1·65	9·	...	Struck the 7·5″ plate 6″ to the left of 6 vertical and 8″ above 2 horizontal. At the back, after rounds 4, 5, and 6, two rivet-heads off; a bulge, and lateral crack across it, in the 5·5″ plate; the backs of the 6·5″ and 7·5″ plates, where struck, could not be seen.
7	548	300-pr	Steel solid shot.	301	Cylindrical. R. E.	14·0	...	45	27	„	4 R	6·2	12·9	1293·1	Struck the 7·5″ plate 8″ to the left of 4 vertical and 7·5″ above 2 horizontal, on a rib; the top of the plate was driven in 1·3″ in a length of 7′; bolt above the hole made by this shot started ·9″; a narrow crack, 4″ long, from the top of the plate; the right side of the plate started out from the backing ·7″ at top and ·8″ at bottom, the left side started out ·5″ at top and ·7″ at bottom; the shot set up 2·25″ and was cracked at the side through the "aillette" holes and also across the rear. At the back twenty rivets broken; no nuts off the through-bolts, but many washers much compressed and altered in form, and two iron tires, for resisting the spread of the washers, driven off, and one broken; angle iron on vertical rib cracked through and bent out; horizontal angle iron cracked and started considerably; fastenings of heavy iron shelf-piece broken, and shelf-piece ready to give way. This plate exhibited a considerable amount of fibre in the hole made by the shot to a depth of 3″ from the front of the plate.
8	549	„	Steel shell.	288	Cylindrical, with cast-iron head.	20·0	11 0	„	25	„	„	...	...	1318·4	Struck the 5·5″ plate 1′ to the right of 2 vertical, and 7″ below 2 horizontal, the shell completely penetrated the plate and burst in the backing, the hole being filled with portions of shell. The diameter of the hole was 14″ × 14·3″; the plate was driven in 1·8″ in a length of 4′, and cracked from the bottom of the hole to the bottom of the plate, and was forced up from the centre plate ·5″ in a length of 4′; started from backing ·7″ at left side; bolt in top row of centre plate started 3″; outside baulk of timber backing driven out at the side 1·7″ and split through its thickness at the top, and the backing at point of explosion completely destroyed and fired. At the back, one vertical rib and angle-iron broken; inner skin and additional iron plates (riveted to back of skin) rent and bulged; depth of fracture and bulge 14″ over an area of 3′ × 3′; horizontal angle-iron along the top cracked and thrust out; washers more squeezed, and more rivets off.
9	550	130-pr Whitworth.	Shell, homogeneous metal.	148	Cylindrical, F. E.	21·0	5 12	25	15	„	2 R	...	...	at 524′ 1267·8	Struck the 5·5″ plate 5·5″ (measuring from circumference to circumference of the holes) to the right of the last round, and 6″ below 2 horizontal, penetrated the plate, and burst in the backing; the timber backing from the hole to the top of the target was completely blown out at the top; diameter of hole 9·5″ × 9″, a narrow crack uniting the two holes. At the back, a slight increase of breakage of rib, and thrusting out of fragments of skin and its support; wooden fibre of backing more protruding.
10	551	L. T.* 9-inch gun.	Steel solid shot.	327	Cylindrical, R. E.	21·5	...	50	20	„	nil.	...	...	at 546′ 1222·0	Missed the target.

* Lynall Thomas's.

Number of round.	Photographic No.	Nature of ordnance.	Projectile. Nature.	Projectile. Weight.	Projectile. Form.	Projectile. Length.	Bursting charge of shells.	Charge in lbs.	Elevation.	Range in yds.	Deflection.	Effects. Depth of indent in inches.	Effects. Diameter of indent in inches.	Remaining velocity.	Remarks.
				lbs.		in.	lbs. oz.		′		′				
11	552	L. T. 9-inch gun.	Wrt. iron solid shot.	302	F. E.	18·5	...	50	30	200	15 R	...	8·5	905·4 doubtful.	Struck at the junction of the 6·5″ and 7″ plates on unbacked portion of plates; the greatest depth on 7·5″ was 5·95″, and on 6·5″ was 4″, the total length of plate driven in was 7′ 6″; the 6·5″ plate was much cracked for a semi-circle of 9″ from the top; a crack ·6″ wide extended from the right from the semi-circle for a length of 1′ 5″, passing through a bolt-hole; a crack 2·5″ long from the left of semi-circle, and a crack from the top of the plate to a bolt-hole at 1′ 9″ from impact. On the 7·5″ plate, a crack ·7″ wide extended from the bottom of the plate to a bolt-hole at 11″ from point of impact, and the plate cracked round parallel to the indent, and 11″ above it. At the back, the 6·5″ plate was cracked through and opened. Four rivet heads off; vertical rib and angle iron cracked through. The shot set up 5·5″.
12	553	„	Hardened steel solid shot.	330	E. E.	21·5	...	„	„	„	10 R	...	...	1222·0	Struck the lower edge of the 7·5″ plate on a bolt, made a semi-circular hole measuring 1′ 9″ × 12·5″ and 7·5″ deep. At the back, one rib and angle irons broken; two other ribs much bent, and their angle irons broken; inner skin and supporting plate bulged and fractured; extent of damage over a surface, 4′ × 2′; bulge of skin about 6″; old loosened shelf-piece wholly detached and fallen; two through-bolts broken; one driven out. The shot broke in half longitudinally.
13	554	300-pr shunt.	Wrt. iron solid shot.	163	Spherical, 10·337 in diameter.	...	...	45	20	„	nil.	3·7	13·	at 508′ 1627·0	Struck the 7·5″ plate on 5 vertical, and 8″ above 2 horizontal; plate driven in 3·75″, and slight crack across indent. Back of plate showed a large seven-starred crack, fissures of cracks ·2″; considerable bulge of plate; adjoining rivets off. Major diameter of shot after firing, 13″.

ON THE

"TIME OF BURNING" OF FUZES UNDER DIFFERENT ATMOSPHERIC PRESSURES.

Extracted from Comptes Rendus hebdomadaires des Séances de l'Académie des Sciences.
Vol. LV. No. 21.

Translated from the French of M. DUFOUR (of Lausanne),

BY MAJOR FITZHUGH, R.A.

UP to the present time there are but few "data" available for an enquiry into the influence exerted by atmospheric pressure on the rate of combustion of fuzes.

These "data" appear also to be sometimes contradictory; thus in 1841 M. Trîga noted an increased rapidity of combustion in candles placed in an enclosure, where the air was under a pressure of three atmospheres, whereas soon afterwards Mr Frankland, during an ascent of Mont Blanc, detected no sensible difference between the combustion of candles burnt at Chamounix and the combustion of those burnt on the top of the mountain.

In 1855, Mr Mitchell, Quarter-master in the English army, communicated to the Royal Society the result of experiments made at various elevations in the Himalayas with military fuzes. His results show that the time of burning increases as the pressure diminishes.

The combustion therefore appears to be less active under a lower pressure.

Mr Frankland last year repeated the experiments of Mr Mitchell and confirmed his results. Mr Frankland experimented on 6-in. fuzes, made at the Arsenal, Woolwich; these fuzes were burnt in a close vessel in air artificially rarefied.

In the experiments of Mr Frankland the pressure unavoidably varied a little during the burning of the same fuze, and in spite of the ingenious contrivances used by this scientific man, it is to be feared that the combustion was influenced by the smallness of the space in which it took place.

In the month of July last, I tested the time of burning of fuzes under circumstances different from those under which the scientific English physician made his experiments; I experimented in the open air, seeking pressures gradually lower and lower at different altitudes in the Alps.

It is very difficult to determine accurately the duration of combustion of a fuze if the observer trusts to being able to note on any sort of time-piece the instant at which the fuze takes fire, and goes out.

Errors in noting these instants, which errors may vary in different cases, are very likely to vitiate the conclusions drawn from the experiments.

In order to avoid this source of error I used an electric machine for registering the duration of combustion.

The fuze was lighted by a pistol, the hammer of which in falling interrupted an electric current.

The burning out of the fuze fired a small quantity of gunpowder, and the explosion caused the fall of a bar of metal, which re-established the electric current.

The time of burning was thus noted on the register by the interval between two continuous currents; this interval is easily expressed in time by a well-known process, which it is useless to explain.

Some preliminary experiments were made to determine the degree of accuracy of which the method and the apparatus were capable. It appeared from these trials that the error could not exceed $\frac{1}{15}$ second.

Two groups of fuzes were tried under five different pressures, varying from 730 millimètres (28·7411 in.) to 538 millimètres (21·1811 in.). The fuzes were not so exactly similar as to give the same time of burning under the same pressure.

To arrive at the influence exerted by the density of the atmosphere, it was necessary to burn a certain number of fuzes at the same station, and to take the mean time of burning; a comparison of these means should show the influence of the pressure.

In order to neutralize as much as possible the difficulty arising from the want of regularity of the fuzes, the mean times of burning were taken at each station after eight or ten trials. Sixty-eight fuzes were burnt at five stations.

The elevated point "des Chenallettes" just above the convent of St Bernard, 9700 pieds above the level of the sea, is the highest station in the series.

After some difficulty the instruments were set up on the rocky ridge which terminates this high point.

The first group of fuzes were very irregular, the second less so.

The means obtained were as follows:—

FIRST GROUP.

Station.	Altitude.	Pressure.	Mean time of burning.	Mean irregularity.
			s.	s.
OUCHY	380 m. 1246·77 Eng. ft.	728 mm. 28·66 in.	9·96	0·52
GOURZE	920 m. 3018·42 Eng. ft.	685 mm. 26·968 in.	10·11	·54
ST PIERRE ...	1640 m. 5380·74 Eng. ft.	628 mm. 24·72 in.	10·52	·50
ST BERNARD	2478 m. 8130· Eng. ft.	568 mm. 22·363 in.	11·20	·55

SECOND GROUP.

Station.	Altitude.	Pressure.	Mean time of burning.	Mean irregularity.
			s.	s.
OUCHY	380 m. 1246·77 Eng. ft.	731 mm. 28·78 in.	9·15	0·23
ST PIERRE	1640 m. 5380·74 Eng. ft.	628 mm. 24·724 in.	10·12	·29
CHENALLETTES	2890 m. 9481 Eng. ft.	538 mm. 21·181 in.	11·09	·26

It appears that in both cases the time of burning increases as the pressure diminishes. To determine the value of this variation between two specified pressures, it is only necessary to divide the increase of time by the whole time of burning at the higher pressure, and by the difference of the pressures. Thus will be obtained a coefficient which expresses the mean increase on unity of the time of burning (1^s) for a decrease of 1 mm. or ·0394 in. of pressure. The fuzes of the first group were too irregular to allow of my using them for the calculation of this coefficient; those in the second group give the following values:—

Between Ouchy and St Pierre	..	0·00104
,, St Pierre and Chenallettes		0·00108

These two coefficients which are nearly indentical show that the increase in the time of burning is proportional to the diminution in pressure. This very simple law has been already pointed out by Mr Frankland,

To compare the values I have obtained with those of Messrs Mitchell and Frankland, it is only necessary to calculate by the aid of their results the coefficient (in millimètres) between the limits of pressure most nearly corresponding to those I have used.

Taking the observations of Mr Mitchell in the Himalayas at the pressures of 752 and 584 millimètres, the coefficient is 0·00161; between 752 mm. and 609 mm. it is 0·00140. Thus the increase of time was a little greater with these fuzes.

Amongst the six pressures which appear inthe experiments of Mr Frankland, the two which agree most nearly with the limits I have used are the second 716·8 mm. (28·189 in.) and the fourth 570·2 mm. (22·441 in.)

Mr Frankland has for the times of burning for these pressures 32·25 s. 37·75 s.

The coefficient from these results is 0·00116. Between Ouchy and Chenallettes my experiments give 0·00111.

This agreement is very remarkable, and the more interesting because the fuzes used by Dr Frankland were different in size, form, and time of burning from those which furnished the results given above.

It may therefore be taken for granted that the time of burning of one of these fuzes increases in the ratio of 0·0011 of its value for each diminution of ·1 mm. (0·0394 in.) of pressure.

These facts are very important in a military point of view, and should be taken into serious consideration whenever the time of burning of a fuze is an essential element of its employment.

At first sight it would appear as if the increase of time of burning when the density of the atmosphere is less, were due to the decrease of oxygen. This cannot be so, as the fuze composition contains in itself a sufficiency of combustible gas in the form of nitrate. To make quite sure that the supply of oxygen from the air does not affect the question, I burnt three fuzes in a large bell filled with pure carbonic acid. The fuze was lighted by an electric current. The mean time of burning under a pressure of 715 mm. (28·15 in.) was 8·57 s.

It is then the purely physical effect of the change of pressure, which acts in such a marked manner on the rate of burning of fuzes.

RESULTS OF EXPERIMENTS

MADE TO TEST

VARIOUS FORMS OF RIFLING.

By JOHN ANDERSON, Esq.

ASSISTANT SUPERINTENDENT, ROYAL GUN FACTORIES.

For some time past a question has been frequently raised in regard to the tendency which different descriptions of rifling have to split the gun.

The power required to give the rotatory motion to the projectile, through the agency of ribs or grooves in the gun, must necessarily cause an opposite straining in the gun tending to open it, or else to break the metal without actually splitting.

We can easily perceive that an inclined surface is more apt to split the structure than a flat or perpendicular surface, but there were no precise data in regard to the position in which different planes stood with respect to each other.

In order to ascertain this point, experiments have been made in the Royal Gun Factories, by preparing cylinders of cast-iron, all of equal strength and area; these cylinders were bored and rifled on the several plans shewn on the accompanying table, and to prevent the risk of error from any exceptional defect of any description, several of each sort have been experimented with.

Into these rifled cylinders there were correctly fitted corresponding plugs of steel representing the projectile; these plugs were made to fit the part representing the gun, and being of steel, which is a stronger metal than the cast-iron cylinders, it was resolved to continue the experiments until a form of rifling was arrived at, in which the steel plug would be broken before the cylinder was split open.

The experiment consisted in fixing one end of the plug representing the projectile in a frame which was immovable, its other end being within the cylinder. The cylinder was fixed in the centre of a lever fulcrum, and capable of having a torsional motion given to it, by the application of weights on the extremity of the lever.

The accompanying table shews the weight required to produce fracture on the several plans of rifling, and the diagrams will explain the exact form of the arrangement of rifling in the several systems.

Table of Experiments on Cast-iron Cylinders, Rifled on various Systems.

No. of Diagram.	Name.	Nature of Rifling.	Breaking Weight in tons at Circumference.	Remarks.
1	Mr Lancaster's . . .	Oval	7·02	
2	Experimental	Decagon.	23·29	
3	Sir W. Armstrong's . .	Three grooved shunt. .	25·65	
4	Commander Scott's . .	Three grooves, but only two ribs bearing . .	27·95	
5	Mr Whitworth's . . .	Hexagon	28·07	
6	Commander Scott's . .	Two grooves opposite to each other	29·00	
7	Experimental	Two grooves opposite to each other	29·18	
8	Mr Lynall Thomas's. .	Three ribs	35·09	
9	Commander Scott's . .	Three grooves	35·30	
10	Sir W. Armstrong's . .	Ten grooved shunt . .	46·50	At this weight the plug broke, and the cylinder shewed a slight crack.

EXPERIMENTS PERFORMED IN THE ROYAL GUN FACTORIES

WITH

"STERRO METAL."

By JOHN ANDERSON, Esq.
ASSISTANT SUPERINTENDENT, ROYAL GUN FACTORIES.

Composition of this alloy as made in the Arsenal at Vienna is,
Copper 60, zinc 41·88, iron 1·94, tin ·156.

And as made at the Polytechnic, Vienna, its composition is,
Copper 60, zinc 46·18, iron 1·93, tin ·905.

Alloys of a similar composition to that of the Austrian metal have been prepared in the Royal Gun Factories, from which a better result has been obtained than from mixtures of the Austrian metal also prepared in the Royal Gun Factories. The subjoined Table shews the results of the experiments with these different specimens.

Composition.	Treatment.	Permanent elongation of ·002 per inch.	Breaking weight.	Ultimate elongation per inch.
Austrian mixture	As received	6·75	26·75	·1″
R. G. Factories mixture of copper 60, zinc 39, iron 3, tin 1·5	Cast in sand	11	21·5	·05″
Do. of copper 60, zinc 44, iron 4, tin 2	do	13·75	19·25	·015″
do do	Cast in iron	17·25	24·25	·016″
do do	Cast in iron, and annealed	15·25	23·25	·02″
do do	Forged red hot	17	28	·045″

Note.—This alloy is said to be the invention of Baron de Rosthorn, of Vienna. It derives its name from a Greek word, signifying "firm." It consists of copper and spelter, with small portions of iron and tin, and to these latter its peculiar properties are attributed.

It has a brass yellow colour, is close in grain, is free from porosity, and has considerable hardness, whereby it is well adapted for bearing-metal, or other purposes where resistance to friction is needed.

Sterro-metal possesses another quality which, in reference to its application for guns, is regarded as more important than its high tenacity, namely,—great elasticity.

The inventor proposes that in heavy ordnance the interior should consist of a tube of sterro-metal, and over this wrought or cast-iron should be shrunk from the breech to beyond the trunnions.—(See an interesting letter in the "Times" of 3rd February, 1863).

THE LOCK OR TURN OF CARRIAGES

AND THEIR

TURNING ANGLES.

By Lieut.-Col. H. H. MAXWELL, R.H.A.

9-pr. Bengal.

Let R=radius of limber-wheel 30 in.

a= distance of limber-hook in rear of centre of axle 6·3 in.

h=vertical height of point of contact of the limber-wheel with friction plate on trail, 28 in.

b=half-width of trail at that point, 4·5 in.

s= half-horizontal chord at point of contact of limber-wheel, 29·9 in.

w=$\frac{1}{2}$ track or gauge of way less width of felloe, 29·6 in.

λ= turning angle, 44° 36′ 28″.

B= breadth of space in which the carriage can just turn, 30·82 ft.

d= horizontal distance between axles, 111 in.

b'=half-width, 31·8 in., and

l=length of pole pair of horses measuring from the centre of limber axle, 121 in.

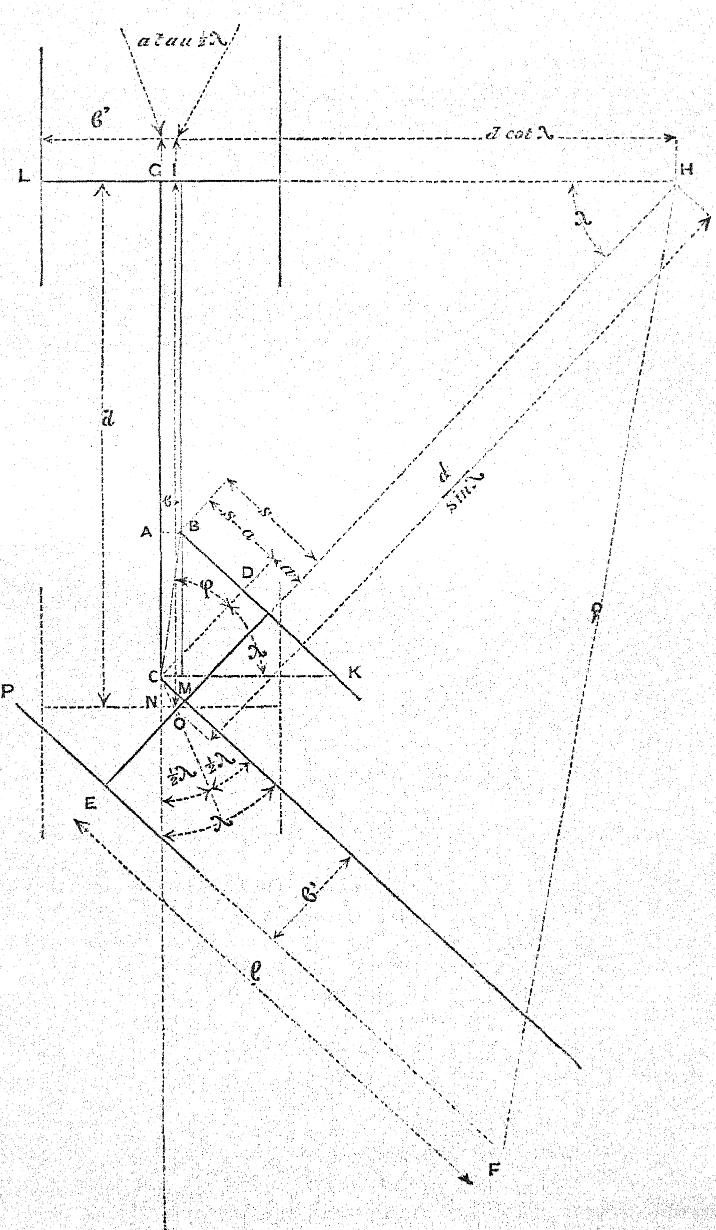
$$\text{Then} \quad \cos(\lambda+\phi)=\frac{b}{w}\cos\phi,$$

$$\text{wherein} \quad \tan\phi=\frac{s-a}{w} \text{ and } s=\sqrt{h(2r-h)},$$

$$\text{and} \quad B=b'+d\cot\lambda+a\tan\tfrac{1}{2}\lambda+\sqrt{\{l^2+(b'+\frac{d}{\sin\lambda}-a\tan\tfrac{1}{2}\lambda)^2\}}.$$

The figure shows the projections on a horizontal plane of the elements of the carriage which have an influence upon its lock and turning angle. The limber is shown in dotted lines with its axle parallel to that of the gun or wagon body, and in thick lines when the carriage is locked; that is, when its limber wheel is in contact with the friction plate on the trail.

Produce the axle of the limber, when locked, until it meets that of the gun or wagon produced in the point *H*, and produce the outer limber-wheel to *F*, *EF* being equal to the length of the pole pair of horses measuring from centre of limber axle or *l*. Join *FH* and draw *CK* parallel to *GH*. The axle of the limber, as aforesaid, is shown in two positions. They intersect



each other at the point O. From O draw OI parallel to GC. Then the $\angle IHO = \lambda = \angle DCK = \angle NCM$. Join CB, B being the point of contact of the inside limber wheel with the friction plate on trail, and draw BA perpendicular to GC; BA represents the half-width of the trail $= b$.

Then, in right-angled triangle BCD, in which

$$BD = s - a, \quad CD = w; \quad \text{put } \angle BCD = \phi,$$

$$\tan \phi = \frac{BD}{CD} = \frac{s-a}{w}.$$

In right-angled triangle ABC, in which

$$AB = b \quad \text{and} \quad \angle ACB = \frac{\pi}{4} - (\phi + \lambda),$$

$$BC = \frac{b}{\sin ACB} = \frac{b}{\cos(\phi + \lambda)} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (\text{I}).$$

Again, in right-angled triangle BCD, in which we have the values of DC and $\angle BCD$ as before,

$$BC = \frac{w}{\sin CBD} = \frac{w}{\cos \phi} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (\text{II}).$$

Equating these two (I. and II.) values of BC,

$$\frac{b}{\cos(\lambda + \phi)} = \frac{w}{\cos \phi},$$

$$\text{hence} \quad w \cos(\lambda + \phi) = b \cos \phi,$$

$$\text{and} \quad \cos(\lambda + \phi) = \frac{b}{w} \cos \phi;$$

from whence having calculated ϕ, we can deduce λ.

On consideration of the figure the least width in which the carriage can turn in, or B, is the sum of the straight lines LH and HF, the latter being the least radius of circle in which the carriage can make a complete circuit, and the former the distance between the centre H and the point L, the outside edge of the wheel of the gun or wagon.

In right-angled triangle IOH, in which we have

$$IO = d, \quad \text{and} \quad \angle IHO = \lambda,$$

$$IH = d \tan \angle IOH = d \cot \lambda,$$

$$\text{and} \quad HO = \frac{d}{\sin \lambda}.$$

In right-angled triangles CNO, CMO, $CM=CN$, CO is common to both, and the angles CNO and CMO are right angles;

$$\therefore \quad \triangle CNO = \triangle CMO,$$

$$\text{and} \quad \angle NCO = \angle MCO,$$

$$\text{and} \quad NO = MO;$$

that is, the angle $NCM=\lambda$ is bisected by CO,

$$\text{and} \quad \angle NCO = \angle MCO = \tfrac{1}{2}\lambda.$$

In right-angled triangle CMO, in which

$$CM = a, \quad \text{and} \quad \angle MCO = \tfrac{1}{2}\lambda, \quad \text{and} \quad \angle CMO \text{ a right angle,}$$

$$MO = NO = a \tan \tfrac{1}{2}\lambda.$$

$$\text{Now,} \quad B = LH + HF,$$

$$\text{and} \quad LH = LG + GI + IH = LG + NO + IH = b' + a \tan \tfrac{1}{2}\lambda + d \cot \lambda.$$

$$HF = \sqrt{EF^2 + EH^2} = \sqrt{l^2 + EH^2};$$

$$\text{but} \quad EH = HO + EO = \frac{d}{\sin \lambda} + EM - OM = \frac{d}{\sin \lambda} + b' - a \tan \tfrac{1}{2}\lambda,$$

$$\text{then} \quad HF = \sqrt{\{l^2 + (b' + \frac{d}{\sin \lambda} - a \tan \tfrac{1}{2}\lambda)^2\}},$$

$$\text{and} \quad B = b' + d \cot \lambda + a \tan \tfrac{1}{2}\lambda + \sqrt{\{l^2 + (b' + \frac{d}{\sin \lambda} - a \tan \tfrac{1}{2}\lambda)^2\}},$$

The following is the calculation for the Bengal 9-pr. gun carriage :—

$$s = \sqrt{h(2r - h)} = \sqrt{28(60 - 28)} = 29{\cdot}9 \text{ in.},$$

$$\tan \phi = \frac{s - a}{w} = \frac{29{\cdot}9 - 6{\cdot}3}{29{\cdot}6}, \quad \text{and} \quad \phi = 38^\circ\ 33'\ 55'',$$

$$\cos(\lambda + \phi) = \frac{b}{w} \cos \phi = \frac{4{\cdot}5}{29{\cdot}6} \cos 38^\circ\ 33'\ 55'',$$

$$\lambda + \phi = 83^\circ\ 10'\ 23''$$

$$\phi = 38^\circ\ 33'\ 55''$$

$$\lambda = 44^\circ\ 36'\ 28''$$

$$\tfrac{1}{2}\lambda = 22^\circ\ 18'\ 14''$$

$$B = b' + d \cot \lambda + a \tan \tfrac{1}{2}\lambda + \sqrt{\{l^2 + (b' + \frac{d}{\sin \lambda} - a \tan \tfrac{1}{2}\lambda)^2\}}$$

$$= 31{\cdot}8 + 111 \cot 44^\circ\ 36'\ 28'' + 6{\cdot}3 \tan 22^\circ\ 18'\ 14''$$

$$+ \sqrt{\{(121)^2 + (31{\cdot}8 + \frac{111}{\sin 44^\circ\ 36'\ 28''} - 6{\cdot}3 \tan 22^\circ\ 18'\ 14'')^2\}}$$

$$= 146{\cdot}88 + 222{\cdot}97 = 369''{\cdot}85 \text{ or } 30'{\cdot}82,$$

ρ or radius in which a complete circle can be made $= FH$ is the quantity under the vinculum,

$$\rho = 222''{\cdot}97 \text{ or } 18'{\cdot}58.$$

The above are the investigation and figure I have made of the formulæ which are given at page 80 of "Hütz and Schmotzl's Handbook of the Royal Bavarian Artillery."

ANNUAL REPORT

AND

ABSTRACT OF PROCEEDINGS OF A GENERAL MEETING OF THE ROYAL ARTILLERY INSTITUTION, HELD ON TUESDAY, MAY 12, 1863.

MAJOR-GENERAL SIR R. J. DACRES, K.C.B. IN THE CHAIR.

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1. IN presenting to the General Meeting the Annual Report and Abstract of Accounts for the year ending 31st March, 1863, the Committee notice with satisfaction the large increase to the number of Members made during the year.

The following Table shows this increase; also the changes in the various Ranks, incident to promotions, deaths, and other causes.

RANK.	£	s.	d.	April, 1862.	Since joined.	Promoted or withdrawn.	Deceased.	April, 1863.
EFFECTIVE LIST.								
General and Regimental Field Officers, paying annually	1	5	0	145	+20	— 2	— 5	158
Captains	0	16	0	341	+44	— 1	— 5	379
Lieutenants	0	10	0	423	+28	— 2	— 4	445
Quarter-Masters	0	10	0	5	1	0	0	6
Riding-Masters	0	10	0	2	1	0	0	3
Surgeons-Major	1	5	0	3	0	0	0	3
Surgeons	0	16	0	6	0	— 1	0	5
Assistant-Surgeons	0	10	0	22	0	— 2	0	20
Veterinary Surgeons	0	10	0	2	0	0	0	2
RETIRED LIST.								
General and Regimental Field Officers	1	5	0	16	+ 4	0	— 2	18
do. do.	0	16	0	2	0	0	0	2
do. do.	0	10	0	8	0	0	— 1	7
do. do.	0	7	6	8	0	0	— 1	7
Captains	5	0	0	1	0	0	0	1
do.	0	16	0	11	+ 2	— 1	0	12
do.	0	10	0	4	+ 2	— 1	0	5
do.	0	5	0	8	0	0	— 1	7
Surgeons-Major	1	5	0	0	2	0	0	2
				1007	+104	—10	—19	1082
Honorary Members	0	10	6	30	+ 3	— 6	— 1	26

Besides the many young officers who, on first being commissioned, have joined the Institution, the Committee observe that the total addition for the year of 107 Members, includes 63 of their brother officers of the late India Artilleries,—an earnest they believe of a further increase when the objects of the Institution are fully known.

A List of Members is, for the first time, printed with this Report. It is not intended to repeat this every year, as a Volume of "Proceedings" when completed (and containing probably more than one Annual Report) would thus be encumbered with many pages of names, needlessly adding to its bulk. Still it is thought that at intervals, of perhaps five or even ten years, such a record of the supporters of the Institution may be acceptable.

2. With regard to the funds, the Committee are glad to inform the General Meeting that, by the produce of the sale of the "Hand Book for Field Service," by economy, and by the steady improvement in the annual income, they have been enabled at the close of the year to re-invest a sum of £500 in 3 per cent. Consols stock, which sum was withdrawn about three years ago, when the funds were less flourishing, for the discharge of outstanding debts.

The Committee are aware that a favourable Balance Sheet is by no means the only criterion of the prosperity of this Institution—the success of which is to be measured rather by what it effects for the good of its Members with the means at its disposal.

The abstract of the year's income and expenditure is shewn on the opposite page.

3. *Printing and Publication.*—Of the means at the disposal of the Committee for effecting the most general good, under the present circumstances of the Regiment, the spread of information on professional subjects, through the printed "Proceedings," seems to be the chief.

The annexed list of Papers, published during the year, shews a large increase in the amount of printed matter put forth; and it is hoped that, in professional interest, these Papers will not contrast unfavourably with the fruit of former years.

While on this subject of publication, the Committee desire respectfully to acknowledge the existence of a more liberal disposition on the part of H.M. Government than prevailed in former times—a disposition to impart more freely the records of experiments affecting Artillery science; to permit the reprinting of these and similar papers; and, in some instances, to allow the Institution to avail itself of the Government type, to work off (at a consequent saving of time and cost) a sufficient number of copies of some good Report, for circulation among its Members.

It is contemplated still further to increase the benefits here alluded to, by a grant of a limited number of copies of *Selections* made from the "Quarterly Abstracts of the Ordnance Select Committee," to be printed by the War Department, and distributed under conditions approved by the Right Hon. the Secretary of State for War and H.R.H. the Field Marshal Commanding-in-Chief.*

The advantage that may be expected from thus imparting knowledge on subjects of present interest, before that interest has died away unsatisfied, can hardly be over-rated, and calls for the thankful recognition of all who will benefit by it.

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* Since this Report was written, Parts I. and II. of these Selections have been issued.

The Committee take this opportunity of acknowledging their obligation to the Director of Ordnance, the Dept.-Adjt. General, the President of the O. S. Committee, and to the Secretary of that Committee who never ceases, in the midst of his own duties, to regard the welfare of the Institution.

General Abstract of the Income and Expenditure of the Royal Artillery Institution,

From 1st April, 1862, to 31st March, 1863.

Dr.

	£	s.	d.
Printing and Publication. Wages	170	9	6
Printing and Publication. Paper	166	15	0
Printing and Publication. Type and Materials	263	5	0
Printing and Publication. Lithography	8	8	0
Chemistry	45	11	1
Photography	158	2	5
Drawing	63	15	8
Lectures	54	4	3
Library, Books, &c.	62	1	2
Museum	29	2	0
Instruments	6	13	6
Carpenter, Materials	56	12	10
Carpenter, Wages	26	2	11½
Insurance (to 31st March, 1863)	10	0	0
Furniture and Repairs	70	5	5½
Subscriptions to Societies	4	4	0
Stationery	47	14	0
Postage and Parcels	29	9	10½
Wages, Clerks and Orderlies	100	10	6
Incidental	44	15	5¾
Due to Messrs Cox and Co., 1st April, 1862	11	0	2
Balance Creditor Consols Stock	1200	0	0
Balance Creditor Cash	100	3	3¾
	£2699	6	2

Cr.

				£	s.	d.
Balance Creditor, 1st April, 1862 ... Consols Stock				700	0	0
Balance Creditor, 1st April, 1862 ... Cash				2	2	10½
Dividend on Consols (to 5th Jan. 1863)				20	4	4
Subscriptions				916	5	6
General Printing				773	15	3
Chemistry				15	5	4
Photography				129	12	0
Drawing				37	7	1
Taxidermy				1	0	8
Library, Books, &c.				19	6	3
Instruments				0	10	0
Carpenter, Wood, &c.				12	0	4
Stationery				56	14	8½
Postage and Parcels				6	10	4
To difference between	£500	0	0			
3 per cent. Consols. Stock, purchased, and amount paid for the same at 92¼ per cent.	£461	17	6			
				8	2	6
				£2699	6	2

May 12, 1862.

(Signed) E. J. BRUCE, Capt. R.A.,
Secretary and Treasurer, R. A. I.

To those officers who have contributed papers to the "Proceedings," whose names follow their respective contributions in the annexed List, the Committee express their sincere thanks,—only regretting that, of the large body of Officers representing the Royal Regiment of Artillery, so few (out of the many who are competent) embrace this opportunity of converting some of their special knowledge and experience into common property, for the good of all. They again invite their brother Officers to make use of this mode of improving the communication between the scattered units of the Corps for the good of the entire Regiment. How much of a practical nature might be gathered from the manifold experience in the various climates in which our Troops are called to serve!

List of "Proceedings," printed during the Year.

On the determination of Range Tables for Rifled Ordnance. By Colonel J. H. Lefroy, R.A., F.R.S.

Remarks on Iron Defences. By Captain H. C. S. Dyer, R.A.

Reports of Experiments carried on at Shoeburyness by the Special Committee on Iron, on the 9th May, 1861, and on subsequent dates.

Remarks on the System of Ordnance calculated to prove the most efficient against Iron-clad Ships and Batteries. By Lieut.-Colonel Boxer, R.A., F.R.S.

Annual Report and Abstract of Proceedings of a General Meeting of the Royal Artillery Institution, held on Tuesday, May 20, 1862; Major-General Sir R. J. Dacres, K.C.B., in the Chair.

The Question of the Day, or "Iron Plates" *versus* "Guns." By Lieut. W. H. Noble, R.A., M.A.

Report of the Minister of Marine, Paris, February 9, 1859, relative to the Proof of Rifled cast-iron Guns, and the revision of former Regulations respecting the fabrication and proof of all iron cannon for the Imperial Naval Service. Translated by Colonel Greathed, C.B., and Colonel J. H. Lefroy, R.A., F.R.S., for the Ordnance Select Committee.

Account of Experiments against Iron Plates, carried on at Shoeburyness, on the 8th April, 1862. Furnished by Captain E. J. Bruce, R.A.

Remarks on permanent Forts and Movable Floating Batteries as a means of Defence against the Bombardment of our Arsenals and Dockyards by an Enemy's Ships. By Lieut.-Colonel E. M. Boxer, R.A., F.R.S.

Account of Experiments carried on at Shoeburyness, on the 26th June, 1862. Contributed by Captain E. J. Bruce, R.A.

Account of Experiment carried on at Shoeburyness, on the 7th July, 1862, to determine the resisting powers of the "Minotaur" class of Men-of-War. Contributed by Captain E. J. Bruce, R.A.

On the adaptation of the Cupola of Captain Coles to Modern Fortresses. By Lieut. F. Duncan, R.A., M.A., F.G.S.

Belgian Experiments on the Proof of Gunpowder in 1858. Extracted from a Report by Lieut.-Colonel C. W. Younghusband, R.A.

Extracts from the Report of an Austrian Military Commission on Gun Cotton. Contributed by Colonel J. H. Lefroy, R.A., F.R.S.

Report on Experiments with Navez's Electro-Ballistic Apparatus. By Captain A. Noble, late R.A.

Description of Navez's Electro-Ballistic Apparatus, for determining the velocity of projectiles. By Lieut. W. H. Noble, R.A., M.A.

Experiments which took place at Shoeburyness, on the 16th and 25th September, 1862, in order to test the penetrating power of the Horsfall Gun.

Account of Experiments carried on at Shoeburyness, on the 13th November, 1862, with Whitworth's Projectiles, fired from the same guns as those used during the Experiments of the 16th and 25th September, 1862. Contributed by Captain E. J. Bruce, R.A.

March of a Half-Battery ("G" Battery, 4th Brigade), Royal Artillery, from St John, New Brunswick, to the Terminus of the Grand Trunk Railway, at Rivière-du-loup on the St Lawrence. February 6th to 16th, 1862. By Lieut. F. M. Smith, R.A.

On finding the Centre of Gravity of a Gun on its Carriage and Limber, or of a Gun on its Carriage unlimbered. By Lieut.-Colonel H. H. Maxwell, R.H.A.

Cupolas and Forts. By Lieut. F. Duncan, R.A., M.A., F.G.S.

Observations upon changes that must be introduced into Works of Defence to enable them to keep pace with improvements in Artillery. By Captain C. S. Hutchinson, R.E.

Account of Experiment carried on at Shoeburyness, on the 29th December, 1862, against a Shield constructed on the principle proposed by Captain Inglis, R.E., representing an Iron Embrasure, for either Casemated or Open Coast Batteries. Contributed by Captain E. J. Bruce, R.A.

Explanatory Statement, and Balance Sheet of the "Crimean Memorial Fund." Furnished by Colonel J. H. Lefroy, R.A., F.R.S.

On the application of Rifled Cannon to the operation of Breaching unseen Defences by High Angle Firing. By Colonel J. H. Lefroy, R.A., F.R.S.

4. *Library.*—The following is the list of books, plans, maps, &c. &c., purchased or presented :—

Lithographic Views of the Crimea	3	Colonel R. Burn, R.A.
Portrait of Lieut.-Gen. the Right Hon. Sir George Murray, K.C.B., &c. &c. &c. and Master-General of the Ordnance ...	1	Captain R. Boyle, R.A.
Gibbon's Artillerist's Manual	1	Colonel F. Eardley-Wilmot, R.A.
U. S. Military Commission to Europe, 1855 and 1856	1	
Benton on Ordnance and Gunnery	1	
Photographic Portrait of Captain Dalghren, U.S. Navy	1	
Negative Photographs of Armstrong Guns packed on Sleighs.	2	
Russian Artillery Journal. Nos. 7 to 12, 1861, and 1 to 10, 1862	16	Colonel N. de Novitzky.
Russian Small-Arms Journal. Nos 1 and 2, 1861, and 1 and 2, 1862.	4	
Experiments on Metals for Cannon and Cannon Powder	1	Secretary for War, War Department, Washington.
Minutes of Proceedings, Institution of Civil Engineers. Vols. XIX. and XX.	2	Institution of Civil Engineers.
Proceedings of the Royal Society. Vols. XI. and XII.	2	Royal Society.
Remarks on the System proposed by the Royal Commissioners for the Defence of the Country, by Lieut.-Colonel E. M. Boxer, R.A., F.R.S.	1	The Author.

Abstracts from Meteorological Observations taken at the Stations of the Royal Engineers in the years 1853, 54, 55, 56, 57, 58 and 59	1	Colonel Sir H. James, R.E.
Militarie Discipline, or the Young Artilleryman (date 1661).	1	Mast-Gunner James Fletcher, R.A.
Reviews of Volunteers in Hyde Park and Edinburgh. (Chromo-Lithos)	2	The Director Topographical Department, War Office.
Map of the country from Vera Cruz to Mexico	2	
Reply to Lieut.-Col Boxer's pamphlet on the system proposed by the Royal Commissioners for the Defence of the Country, by Col. J. H. Lefroy, R.A. ...	1	The Author.
Herzeogovina, or Omar Pasha and the Christian Rebels, by Lieut. G. Arbuthnot, R.H.A.	1	The Author.
Report and Photographs of Experiments carried on by the Special Committee on Iron, at Shoeburyness, between January 1861, and March, 1862	3	The Secretary of State for War, through the Director of Ordnance.
Danish Artillery Journal 1855 to 1861, inclusive, and Nos. 1 and 2 for 1862...	7	Major H. de Jonquieres, Danish Artillery.
Undersögelser betrœfende Skydning, by H. de Jonquieres	1	
Maps of the Yang-tse-Kiang river, from Capt. Blakiston's survey in 1861, and Mongolia or Chinese Tartary.	4	Captain T. W. Blakiston, R.A.
Five months on the Yang-tse, by Capt. T. W. Blakiston, R.A.	1	
Collection of Maps and Surveys of, and observations taken at, Canton	...	The Widow of the late Brig.-Gen. W. T. Crawford, R.A. through Col. Buchanan, R.A.
Photographs of Men and Horses of the Royal Artillery, shewing arrangement of Dress and Appointments	19	The Dep.-Adjt.-General, Royal Artillery, Horse Guards.
Observations on the Guns, Carriages, and Ammunition, and instructions for the care and use of Armstrong Guns. (Land Service)	1	
Books on Artillery and Fortification,— Fortificatione Della Citta, par Maggi and Castriotto. Venice, 1564. 1 Vol. Elements de Fortification, par M. Le Blond. Paris, 1775. 1 Vol. Traité complet de Fortification, par Noizet de St Paul. Paris, 1818. 2 Vols. De l'Attaque et de la Defense des Places, par Vauban. La Haye, 1746-7. 2 Vols. Memorial de Cormontaingne, par Bousmard. Berlin, 1803. 1 Vol. Vegetius Renatus et alii Scriptores Antiqui de re Militari. Versaliœ, 1670. 2 Vols. La Connoissance Parfaite des Chevaux. Paris, 1741. 1 Vol. Essai sue les murs de Revertment, par Merks. Paris, 1841. 1 Vol.	11	C. Monro, Esq., by desire of the late Lieut. K. Monro, R.A.
Dutch Artillery plates	4	Major Delprat, Dutch Artillery.

Notices sur les objets envoyés a l'exposition de Londres. De l'annee, 1862.	1	Mr Cole, Super. Department of Science and Art, Brompton, through Major C. H. Owen, R.A.
A series of Stereograms taken at Hydrabad and Secunderabad, India, by Capt. A. N. Scott, R.A.	94	Captain A. N. Scott, R.A.
Smithsonian Miscellaneous Collections. Vols. I.—IV.	4	Smithsonian Institution, Washington, U.S.
Meteorological Observations	1	
Annual Report, Smithsonian Institution, 1860	1	
The organization, composition, and strength of the British Army	2	The Secretary of State for War, through the Director Topographical Department.
Lithographs of Guns, Carriages, Wagons, &c	32	Royal Carriage Department.
Photographs of Guns, Carriages, Wagons, &c	34	Photographical Establishment, War Department.
Journal of the Royal United Service Institution (Nos. 21 to 24)	...	The Council R.U.S. Institution.
Examination Papers, Royal Military Academy. June and December, 1862.	2	The Insp. of Studies, R.M.A.
Official illustrated Catalogue of the International Exhibition of 1862	4	Captain H. B. Sandford, R.A.
Catalogues of the Maps, Plans, and other Publications of the Ordnance Survey of England and Wales, Scotland, and Ireland	3	The Director of the Ordnance Survey, Southampton.

Books Purchased.

Meyrick's Ancient Armour, 3 vols.	3
The Harbours of England, by Ruskin and Turner	1
Feiling's German Guide	3
,, Complete Guide to German Literature	3
The Weather Book, by Rear Admiral FitzRoy	1
Ganot's Physics, by Atkinson	1
Herschel's Outlines of Astronomy	1
Gould's Birds of Great Britain. Parts 1 and 2	2
The Ibis (periodically)	3
The Nautical Almanack, 1863	1

Publications of Learned Societies. Periodically.

Comptes Rendus.
Le Spectateur Militaire.
Journal de Mathématiques.
Journal des Sciences Militaires.
Journal des Armes Speciales.
Journal of the Society of Arts.
Art Journal.
Proceedings of the Royal Society.

The sale of the photographs executed at the Photographic Department of the War Office, has been very great, exceeding 900, involving much additional work in completing the numerous orders received.

The excellent lithographs drawn in the Carriage Department, of materiél produced there, have had a more limited sale; it is thought that they may not be so generally known.

Lists of both photographs and lithographs are sent to Members, from time to time, corrected to the latest issues.

5. *Museum.*—During the past year the Museum has been enriched by many valuable donations. In ornithology there have been presented by Captain Keate, R.A. humming birds and others from Trinidad—these have been grouped in a separate case, as showing a portion of the fauna of that island; by Captain Freeth, R.A. some humming birds and nests; by Captains Barton and Tweedie, R.A. specimens from North America; by Lieut. Slessor, R.A. others from Bermuda and Demerara. A valuable collection has been given by Lieut. Maule, R.A. from Madagascar; by Capt. Blakiston from China; by Asst.-Surg. W. Temple, R.A. from New Zealand.

From J. K. Lord, Esq. some rare and valuable specimens from California have been received; also a splendid collection from British Columbia, of animals, birds, eggs, and insects. Time has not been given, since the arrival of these specimens, to prepare a proper catalogue for this Report.

The collection of British birds proceeds very slowly, the only additions for the past year, being a pair of the common, and a pair of the red-legged partridge, presented by Major Ingilby, R.A.; it is much to be hoped that Members who have the opportunity will assist in the completion of this most interesting part of the Museum.

Game birds from all parts of the world are requested. They are of interest not only to the naturalist, but also to the sportsman. Such a collection at the Institution, properly classified according to locality, would be found useful to Members when ordered on Foreign service, for consultation as to what they might expect in the way of sport, if not for any more scientific purpose.

In conchology great progress has been made, Lt.-Col J. Desborough, R.A. having contributed a large collection, numbering more than 700 specimens, many of them very fine, and in good condition.

Entomology has this year been a blank, with the exception of what has been presented by Mr Lord; there is however a promise of 250 specimens from India, by Lieut. Hime, R.A., and specimens from other quarters would be much valued.

Presentations to the Museum.

Collection of Silver and Copper Coins (chiefly English)	...	Captain Sandilands, R.A.
Specimen of the Finest Grain or Stream Tin, from the neighbourhood of St Anstle, Cornwall	1	Mr Fullom, R. C. D.
Samples of the ingredients (at different stages) used in the Manufacture of gunpowder. Also of gunpowder varying in size of grain	43	Colonel W. H. Askwith, R.A., Superintend. Royal Powder Factories, Waltham Abbey.
Birds from New Zealand*	15	Assist.-Surgeon W. Temple, M.B., R.A.

* Vide Appendix I. p. 286.

Maori (New Zealanders) Fish Hooks	3	Lieut. A. F. Pickard, R.A.
English Partridges	4	Lt.-Col. C. H. Ingilby, R.A.
Geological Specimens (Aberdeen Granite)	7	H. Ramage, Esq., Aberdeen.
Instrument for laying Mortars	1	Lieut. D. Cameron, R.A.
Humming Birds, and others	52	Captain E. Keate, R.A.
Birds from British Columbia	123	J. K. Lord, Esq., Boundary Commission.
Animals, do do	19	
Birds from California[1]	38	
Animal do	1	
Eggs do	6	
Specimens of Small Fish[2]	17	Sir J. Richardson, through Lieut. Richardson, R.A.
Humming Birds	10	Captain R. K. Freeth, R.A.
Nests	2	
Snake (Cobra)	1	Maj.-Gen. W. F. Forster, K.H.
Fish (Saw)	1	
Nest	1	
Large Collection of Shells; Chinese Flag, taken by Lieutenant-Colonel J. Desborough, R.A., at the Capture of Tang-Ku	...	Lt.-Col. J. Desborough, R.A.
Impeyan Pheasants	2	Lieut. E. S. Burnett, R.A.
Skulls of Beaver and Dog	2	Lieut. B. J. Bonnor, R.A.
North American Birds[3]	10	Captain J. Barton, R.A.
do do[4]	5	Captain M. Tweedie, R.A.
Bullets of, and Apparatus for Firing the Danish Infernal Machine, which fires 90 shots per minute	set	Major W.H. Goodenough, R.A.
Indian Butterflies	28	Colonel J. H. Lefroy, R.A.
Insects from Western Africa	4	Mr Whitely.
Birds (West Indian)[5]	6	Lieut. E. A. Slessor, R.A.
Shells do	2	
Fragments of Whitworth's Steel Shells	11	Commandant of the School of Gunnery, Shoeburyness.
Russian Sword Blades of Col. Obookhof's Cast Steel, awarded a Prize Medal at the International Exhibition, 1862	3	Colonel N. de Novitzky.
Fragments of Shot and Shell	15	Special Committee on Iron.
Specimens of Steel, Wrought, and Cast-iron Shot, fired from Rifled Wall Piece	12	
Chinese Bank Note	1	Captain T. A. J. Harrison, R.A.
do Pawn Ticket	1	
do Officer's Pass	1	
do Private's do	1	
Madagascar Birds[6]	43	Lieut. G. E. Maule, R.A.
Chinese Model of Fire Engine	1	Vet.-Surg. J. B. W. Skoulding, R.A.
do Water Cart	1	
Head of Rat-tail Snake	1	Lieut. J. F. Owen, R.A.
Chinese Birds[7]	62	Captain T. W. Blakiston, R.A.
Minerals from the Yang-tse[8]		do

[1] Vide Appendix I. p. 284. [2] Ibid, p. 288. [3] Ibid, p. 284. [4] Ibid.
[5] Ibid, p. 286. [6] Ibid, p. 287. [7] Ibid, p. 285. [8] Ibid, p. 288.

6. *Languages.*—The classes for the Study of the French and German languages have met as usual, intermitting only the periods of the summer and winter vacations at the R. M. Academy.

7. *Surveying and Practical Astronomy.*—During the past year several Officers have taken advantage of the Institution, to obtain a knowledge of these branches. They have received instruction in finding latitude and longitude, in working lunar observations, in the use of the transit, and altitude and azimuth instrument.

It is expected that very shortly Mr Barlow's large telescope will be mounted at the Observatory, when various celestial objects may be viewed by its aid.

8. *Photography.*—The Photographic rooms and apparatus were never in such good working order as at the present time. The Committee are partly indebted for the improvements that have been effected to the advice and practical knowledge of Lieut.-Colonel Desborough.

A small portrait camera and lens, for "carte de visite" likenesses, has been added, and has afforded entertainment to many.

As the season advances, a Class will be formed for instruction, as was done last year, only under different auspices.*

9. *Chemistry.*—The Chemistry Class, under the able instruction of Mr Bloxam, has met once a week, with the usual intervals at Midsummer and Christmas. Every member is free to pursue his researches, at his own discretion, during the week.

10. *Taxidermy.*—It is to be regretted that this Class has not been resumed at the Institution. But the Committee are glad to learn that, both at the upper and lower Cadet Barracks, Mr Whitely has pupils who work with him during their spare time. The Lieut.-Governor and the Inspector of Studies recognize the wholesome character of such a pursuit—leading as it often does to a thorough love for ornithology, and bringing to the sportsman a new resource.

The gentlemen who, as Officers, have contributed most ably to the Natural History Museum, are for the most part those who took up this pastime as Cadets. It may be permitted here to mention with interest one who, having left the Regiment, still adds liberally to his former gifts, who is now engaged in geographical exploration, and in widening his knowledge of Natural History; the Committee refer to Captain Blakiston, who last year received, for his enterprising survey of the "Yang-tse-Kiang," the Gold Medal of the Geographical Society.

11. *Drawing.*—Mr Aaron Penley continues to have a large Class of Officers for landscape drawing.

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* This Class has since been formed, and has commenced work.

12. *Lectures.*—In addition to the regular courses of Lectures to the Gentlemen Cadets, comprising Natural Philosophy, Applied Chemistry, Practical Mechanics, Mineralogy, and Geology, all of which are delivered in the Theatre of the Institution, and to which all Members have access, other Lectures have been provided by the Committee for the Members and their families, such as Lectures by Mr Goodeve, Professor of Mechanics, R.M. Academy, "On Sound, Light, and Heat, considered as modes of Motion;" by Mr Bloxam, Lecturer on Chemistry, R.M. Academy, "On the Chemical Relations subsisting between Fuel and Fire." The Committee desire also to express their thanks to T. Howell, Esq., for a paper kindly read by him on "A Day's Sight-seeing in Japan," and to the Chemist to the War Department, Mr Abel, for his interesting Lecture "On the Treasures hid in Coal-Tar."

13. *Evening Meetings.*—Members are still invited to send papers to be read at these Meetings, which are held at no fixed periods, but are convened when the Committee have before them matter likely to lead to interesting discussion.

The thanks of the Committee are due to Captain Hutchinson, R.E., for a paper read by him at one of these Meetings, entitled "Observations upon changes that must be introduced into Works of Defence to enable them to keep pace with Improvements in Artillery." The same is printed in the "Proceedings."

14. *Model Room.*—The very complete collection of all service projectiles, fuzes, tubes, &c. &c., whole and in section, prepared by the Superintendent Royal Laboratories, and presented by H. M. Government, on the application of the Committee through the Director of Ordnance, now forms one of the most instructive features in the Institution.

This collection forms the groundwork of what may grow into a useful assortment of military models.

A list of these Laboratory specimens is given in Appendix II. p. 289.

15. *Ancient Arms and Uniforms.*—The additions to this branch have been insignificant. The mounting of two figures with suits of Pikemen's and Cuirassier's armour is in progress.

Also cases are in course of construction to contain, among other things, some of the suits of Officers' uniforms already received. Contributions of any parts of the uniforms formerly worn by Officers of Royal Artillery, even down to the latest change, will be gladly received.

The Committee regret that from China and India they have received so few contributions of native arms.

16. *Photographic Likenesses and Views of Foreign Stations.*—A handsome book has lately been procured to contain the likenesses of officers already received; these are chiefly of two kinds, one—and this the preferable size—a three-quarters figure, on a plate $8'' \times 10''$; the other, "carte de

visite" size. They consist of Officers both in and out of uniform; of course the former is preferred.

All who have not yet contributed to this only Regimental Collection are strongly urged to do so.

Photographic views of Foreign Stations have been received from Lieut. Hon. A. B. de Montmorency, R.A. of the Artillery Mess House and Mess Compound, Bangalore, India; and from Lieut. A. B. Browne, R.A. a series of views of Gibraltar.

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1. *Proposed by Sir R. J. Dacres, seconded by Colonel Buchanan, and carried,—*

"That the Report of the Committee be received and adopted."

2. *Proposed by Major Reilly, seconded by Major Field, and carried,—*

"That the Committee be requested to make application to the Secretary of State for War, that copies of all Blue Books and State Papers, of general and professional interest, be presented to the Institution, as was done, under the late Board of Ordnance, to the Royal Artillery Library."

3. *Proposed by Lt.-Col. Desborough, and seconded by Major Field,—*

"That in any future edition of the 'Hand Book for Field Service' which may be published by the Institution, every Member shall receive a copy of the same gratis."

To this proposition an amendment was moved by Major Reilly, seconded by Colonel Buchanan, and carried,—

"That this question be referred to the Committee for report at the next General Meeting."

4. A vote of thanks was passed to the Secretary.

5. *Addition to Rule IV. proposed by Committee, seconded by Colonel Buchanan, R.A., and carried,—*

"That the Director of Artillery Studies be, *ex officio*, a Member of Committee."

6. *Change in Rule XV., proposed by Committee, seconded by Lieut.-Col. Desborough, R.A., and carried,—*

"That, owing to the difficulty sometimes found in obtaining the attendance at Committee Meetings of five Members to form a quorum, in future the Committee may proceed to business with three instead of five Members, and that Rule XV. be altered accordingly."

In accordance with Rule IV. the following officers withdraw from the Committee :—

Lieut.-Colonel Clerk.	Surg.-Major H. Briscoe, M.D.
Captain T. L. Dames.	Major Owen.

Captain T. C. Molony.

It was resolved that the undermentioned officers be requested to serve in their room :—

Lt.-Col. Bowie.	Surg.-Major Fogo, M.D.
Lt.-Col. Desborough.	Major FitzHugh.

Major Field.

And Captain Brackenbury in place of Major Goodenough, who has left the Garrison.

7. The Committee for the ensuing year will therefore stand thus :—

PATRON AND PRESIDENT:

Field Marshal H.R.H. the Duke of Cambridge, K.G.

VICE PRESIDENTS:

The Commandant.
The Deputy-Adjutant-General.

MEMBERS:

The Assistant-Adjutant-General.
The Secretary Ordnance Select Committee.
The Brigade-Major.
The Director of Artillery Studies.

Colonel J. Travers.	Major H. T. FitzHugh.
Lt.-Col. J. H. Smyth, C.B.	Captain H. A. Doyne.
,, J. R. Gibbon, C.B.	,, C. B. Brackenbury.
,, C. V. Bowie.	,, V. D. Majendie.
,, J. Desborough.	Lieut. F. S. Stoney.
Surg.-Major J. M. S. Fogo.	,, H. Edmeades.
Major G. T. Field.	,, W. G. Stirling.

Captain E. J. Bruce, *Secy. and Treasurer.*

(Signed) R. J. DACRES, Major-General,
Vice-President, in the Chair.

May 12, 1863.

APPENDIX I.

North American Birds, presented by Captain Barton, R.A.

Cat. No.	Species.	Sex.	Locality.	Orig No.	Common Name.	Date.
448	Circus hudsonius	♀	....	—	Marsh hawk	—
449	Ceryle alcyon	—	....	—	Belted kingfisher	—
450	Tyrannus carolinensis	—	....	—	King bird	—
451	Junco hyemalis	—	....	—	Snow bird	—
452	Melospiza melodia	—	....	—	Song sparrow...............	—
453	Icterus baltimore	♂	....	—	Baltimore oriole...........	—
454	Quiscalus versicolor	—	....	—	Crow blackbird	—
455	Ectopistes migratoria	—	....	—	Wild pigeon	—
456	Botaurus lentiginosus	—	....	—	Bittern	—
457	Colymbus torquatus	—	....	—	Northern diver	—

North American Birds, presented by Captain Tweedie, R.A.

458	Pyranga rubra	♂	...... Toronto......	—	Scarlet tanager	—
459	„ „	♂	...... „	—	„ „	—
460	Squatarola helvetica...............	—	...... „	—	Blackbellied plover	—
461	Strepsilas interpres	—	...... „	—	Turnstone	—
462	Tringa alpina..........................	—	...... „	—	Redbacked sandpiper ...	—

California Birds, presented by J. K. Lord, Esq.

463	Strix nebulosa	♂	....	9	Western barn owl.........	—
464	Athene hypugaea	—	....	—	Burrowing owl	Jan. 62
465	Tyrannus domincensis	♀	Napa Valley	26	Grey king bird	May „
466	Tyrannus mexicanus	♂	Cape St Lucas ...	6410	....	1860.
467	Dendroica audubonii	♀	....	25	Audubon's warbler	—
468	Collyrio excubitoroides............	♂	Napa Valley	39	White-rumped shrike ...	May 61
469	Campylorhynchus affinis	♀	Cape St Lucas ...	4618	....	Apr. 60
470	„ „	♂	„ „ ...	4997	....	do
471	Thriothorus bewickii	♀	....	28	Bewick's wren	—
472	Junco oregonus.......................	♀	....	40	Oregon snow bird	—
473	Pipilo albigula...	♀	Cape St Lucas ...	4634	....	Apr. „
474	„ „	♂	„ „ ...	5003	....	do
475	Pipilo mesoleucus	♀	....	20	Cannon finch...............	—
476	Tanagra vicarius	♂	Mexico	27	Blue tanager	—
477	Xanthocephalus icterocephalus	♂	....	21	Yellowheaded blackbird	—
478	Icterus bullockii	♂	....	43	Bullock's oriole	—
479	Cyanocitta californica	♂	....	17	California jay...............	—
480	Oreortyx pictus	♀	....	14	Plumed partridge	—
481	Lophortyx californicus............	♂	....	15	California quail	—
482	„ „	♀	....	16	„ „	—
483	Garzetta candidissima	♂	....	2	Snowy heron	—
484	Ardea herodias	♀	Cape St Lucas ...	6008	Great blue heron	Apr. 61
485	Tringa wilsonii	♂	San Francisco ...	29	Least sandpiper...........	„ 62
486	Limosa fedoa	♀	....	19	Marbled godwit............	—
487	Rallus virginianus	♂	Retaluma, Cala...	37	Virginia rail	Mar. „
488	Rallus elegans	♂	....	18	Marsh hen	—
489	Squatarola helvetica..............	♀	....	—	Blackbellied plover	Apr. „
490	Aix sponsa	♂	Retaluma, Cala ...	5	Summer duck	—
491	Querquedula cyanoptera	♂	....	11	Redbreasted teal	—
492	„ „	♀	....	12	„ „	—
493	Erismatura rubida	♀	....	13	Ruddy duck	—

Cat. No.	Species.	Sex.	Locality.	Orig No.	Common Name.	Date.
494	Graculus dilophus	♂	Farallones island	3	Double crested cormorant	April, 1861
495	Chroicocephalus atricilla	♀	,, ,,	38	Laughing gull	do
496	Larus nigricans	♂	,, ,,	4	Black gull	do
497	Cerorhina monocerata	♂	,, ,,	6	Sea hornbill	do
498	Colymbus pacificus	♀	,, ,,	9	Pacific diver	do
499	Uria lomvia	♀	,, ,,	8	Foolish guillemot	do
500	Uria colunba	♂	,, ,,	7	Black guillemot	do

Eggs.

Lophortyx californicus............2 Specimens.
Cerorhina monocerata ....4 do.

Animal.

Mephitis occidentalis .... California Skunk.

Chinese Birds, presented by Captain Blakiston, R.A.

501	Hirundo javanica	—	Canton	531	Swallow	April 4, 60
502	Alcedo bengalensis	—	,,	534	Kingfisher	,, 10 ,,
503	,, ,,	—	,,	557	,,	July 3 ,,
504	Ruticilla aurorea	♂	,,	609	Spotwing redstart	Oct. 27 ,,
505	Ianthia cynura	♂	,,	665	Blue tail	Jan. 4, 61
506	Pratincola indica	♂	,,	540	Stone-chat	April 10, 60
507	,, ,,	♂	,,	600	,,	Oct. 18 ,,
508	Cossyphus saularis	♂	,,	545		June 13 ,,
509	,, ,,	♀	,,	593		Sept. 21 ,,
510	Parus cinereus	♂	,,	546	Grey tit	June 16 ,,
511	,, ,,	♂	,,	610	,,	Oct. 24 ,,
512	Leiothris sinensis	—	,,	909		—
513	,, ,,	—	,,	921		—
514	Motacilla boarula	—	,,	543	Grey wagtail	April 7 ,,
515	,, ,,	—	,,	627	,, ,,	Oct. 24 ,,
516	,, lozonensis	♀	,,	599		,, 19 ,,
517	,, ocularis	♀	,,	598		do
518	,, ,,	♀	,,	625		,, 20 ,,
519	Turdus mandarensis	♀	,,	562	Chinese blackbird	July 5 ,,
520	,, ,,	—	,,	629	,, ,,	Oct. 26 ,,
521	Petrocossyphus manillensis	—	,,	590	Rock thrush	,, 10 ,,
522	,, ,,	—	,,	628	,, ,,	—
523	Garrulax perspicillatus	—	,,	554		June 20 ,,
524	Pycnonotus occipitalis	—	,,	526	Bulbul	April 7 ,,
525	,, ,,	—	,,	528	,,	do
526	,, ,,	—	,,	—	,,	—
527	Pycnonotus jocosus	—	,,	555	,,	June 26 ,,
528	Muscicapa cinero-alba	—	,,	613		Oct. 24 ,,
529	Niltava cyanomelœna	—	,,	535	Blue bird	April 7 ,,
530	Dicrurus cineraceus	♀	,,	563	Drongo	June 28 ,,
531	,, ,,	—	,,	565	,,	do
532	Lanius schach	—	,,	572	Sparrow king	Aug. 3 ,,
533	,, ,,	—	,,	574	,, ,,	,, 12 ,,
534	Pica sericea	—	,,	501	Chinese magpie	May 26 ,,
535	,, ,,	—	,,	502	,, ,,	,, 22 ,,
536	Acridotheres cristatellus	—	,,	505	Chinese crested starling	,, 19 ,,
537	Gracupica nigricollis	—	,,	509	Magnal	,, 21 ,,
538	Temenuchus turdiformis	—	,,	520		,, 19 ,,
539	,, ,,	—	,,	521		do
540	Fringilla sinica	—	,,	916	Chinese greenfinch	—
541	Passer montanus	—	,,	547	Mountain sparrow	June 13 ,,
542	,, ,,	—	,,	548	,, ,,	,, 14 ,,
543	,, ,,	—	,,	549	,, ,,	,, 16 ,,
544	,, ,,	—	,,	550	,, ,,	,, 13 ,,
545	,, russatus	—	,,	911	Ruddy sparrow	—
546	Emberiza fucata	—	,,	908	Painted bunting	—
547	,, personata	♀	,,	641	Masked bunting	Nov. 7 ,,

Cat. No.	Species.	Sex.	Locality.	Orig No.	Common Name.	Date.
548	Emberiza personata	—	Canton	907	Painted bunting	—
549	Melophus lathami	♀	"	566	Latham's finch	June 29, 60
550	" "	♂	"	567	" "	" 22 "
551	Yunx torquilla	—	"	530	Wryneck	April 14 "
552	Cuculus orientalis	♀	"	568	Indian cuckoo	Aug. 16 "
553	Megalæma virens	—	"	912		—
554	Centropus affinis	♀	"	586	Larkheel	Oct. 18 "
555	Turtur chinensis	—	"	511	Chinese turtle dove	May 21 "
556	" "	—	"	512	" "	do
557	Turtur chinensis	—	"	564	"	June 20 "
558	Ardeola speciosa	—	"	517	White winged egret	April 14 "
559	" "	—	"	903	" "	—
560	Ardetta cinnamomea	♀	"	515	Striped egret	April 13 "
561	" "	—	"	917	" "	—
562	Gallinula stenura	—	"	523	Narrow-tailed snipe	April 10 "

Birds presented by Assist.-Surgeon W. Temple, R.A.

						Native name.
563	Hieracidea novæ zelandiæ	—	New Zealand	14	New Zealand falcon	Kahu
564	Hieracidea brunnea	—	"	12		Karewarewa
565	Milvus melanotis	—	Cape de Verd islands	2		—
566	Halcyon vagans	—	New Zealand	7	N. Zealand kingfisher	Kotoretaro
567	" "	—	"	"	" "	"
568	Prosthemadera novæ zelandiæ	—	"	8	Poe bee-eater	Tui
569	Rallus aquaticus*	—		1	Water rail	—
570	Puffinus tristis	—	New Zealand	—		—
571	Puffinus assimilis	—	North of N. Zealand	4		—
572	Thalassidroma melanogaster	—	New Zealand	15		—
573	Procellaria æquinoctialis	—		3	Great black petrel	Takupu
574	Prion vittatus	—	New Zealand	5	Broad-billed petrel	—
575	" "	—	"	"	" "	—
576	Diomedea exulans	—	"	9	Wandering albatros	—
577	" "	—	"	"	" "	—
578	Diomedea brachyura	—	"	6	Short-tailed albatros	—

Birds presented by Lieut. Slessor, R.A.

579	Buteo buzon	—	Demerara	—	Hobby buzzard	—
580	Buteo	—	"	—		—
581	Ceryle alcyon	♀	Bermuda	—	Belted kingfisher	—
582	Aramus scolopaceus	—	Demerara	—	Scolopaceous heron	—
583	Butorides virescens	—	Bermuda	—	Green heron	—
584	Sterna magnirostris	—	Demerara	—		—

* Caught in the rigging of the ship, off the coast of France, lat. 46′N, long. 12′W.

Madagascar Birds, presented by Lieut. G. E. Maule, R.A.

Cat N°.	Eur. name.	Native name.	Classical name.	Where shot.	N°.	When shot.	Remarks.
585	Thrush	Horova	Hypsipetes ouravang	Soumandrakasi	1*	Sept. 23, 62	Iris, *dark brown;* legs, *light brown;* beak, *yellow.*
586	Nightingale	Veronbendrana	... ...	Hivoondroo	2	" 9 "	Iris, *hazel;* upper mandible, *dark brown;* lower mandible, *dusky orange;* interior of mouth, *bright orange;* legs, *brownish lead colour.*
587	... ...	Veronrersatsat	Leptopterus viridis	Hivoondroo	3*	" 9 "	Skin round eye, *bright blue;* beak, *bluish lead;* iris, *hazel.*
588	Wagtail	... ...	Mootacilla flaviventris	Foule point	4	" 14 "	Iris, *dark brown;* beak, *black;* legs, *dark lead.*
589	Kingfisher	Vintch	Corythornis vintsioides	Hivoondroo	5*	" 8 "	
590	Bee-eater	Kereo kereo	Merops superciliosus	Hivoondroo	6	" 9 "	Iris, *red;* beak, *black;* legs, *brown.*
591	Goatsucker	Tar tar	Caprimulgas madagascariensis	Sand bank hivoondroo	7	" 9 "	Supposed to have had a nest near where this bird was shot.
592	... ...	Tulu	Centropus tolu	Tamatave	8	" 13 "	Iris, — beak, *black;* legs, *black.*
593	Shrike	Drouga	Dicrurus forficatus	Hivoondroo	9	" 8 "	Iris, *brown;* beak, *black;* legs, *black.*
594	Hawk	Hitsi kitsi	Tinnunculus	Foule point	10	" 14 "	Iris, *hazel;* legs, *greenish yellow.*
595	Pigeon	Funang	Vinago australis	Ambouedimond	11	" 28 "	Iris, *light blue;* beak, *horn colour;* basal half, *lake;* legs and claws, *yellow.*
596	Heron	Tambac karatzi	Ardea atricapilla	Hivoondroo	12	" 22 "	Iris, *yellow;* outer circle, *red;* beak, upper mandible, *black;* lower mandible, *greenish yellow;* legs, *yellow;* streak of greenish yellow from upper mandible to eye.
597	Pratincole	Vecco vecco	Glareola geoffroyi	Hivoondroo	13	" 25 "	Iris, *brown;* beak, *black;* base, *vermillion;* claws, *brownish red.*
598	Lark	Bouria	Mirafra hova	Foule point	14	" 15 "	Iris, *brown;* beak and legs, *flesh colour.*
599	Sunbird	Shonia	Nectarina souimanga	Feneriffe	15	" 25 "	Iris, *brown;* beak and legs, *black.*
600	Quail	Trow trow	Magaroperdix striata	Hivoondroo	16	" 22 "	
601	Tern	... ...	Sterna caspia	Hivoondroo	17	" 9 "	Iris, *brown;* beak, *greenish yellow;* legs and feet, *black;* upper surface of toes, *flesh colour.*
602	... ...	Ting ting	Drymœca madagascariensis	... ...	18	...	Iris, *light brown;* upper mandible, *dark brown;* lower mandible, *lighter;* feet and legs, *flesh colour.*
603	Purple Heron	Long ourouf	Ardea perpurea	Hivoondroo	19	...	Iris, *yellow;* beak, *greenish yellow;* upper mandible, *dusky;* legs and front, *dark brown;* legs and hind, *yellowish.*
604	... ...	Tsiri tsiri	Dendrocygna viduata	Hivoondroo	20	Sept. 27, 62	
605	Egret	Verori ombi	Ardea	Soumandrakasi	21	" 8 "	Iris, *yellow;* legs and beak, *yellow.*
606	Chicana	Verontsarauongy	Parra albinucha	Feneriffe	22	" 18 "	Iris, *grey;* legs, *grey;* head of beak, *light blue.*
607	Sunbird	Shouia	Nectarina angladiana	Ambouedimond	23	" 28 "	Iris, *dark brown;* beak and legs, *black.*
608	Quail	Trow trow	Margaroperdix striata	Foule point	24	" 15 "	Female.
609	Stonechat	Fettah	Pratincola sybilla	Feneriffe	25	" 18 "	Iris, *dark brown;* beak and legs, *black.*
610	Crow	Quork	Corvus madagascariensis	Soumandrakasi	26	" 24 "	Iris, *brown;* beak and legs, *black.*
611	Duck	Veron cosia	Nettapus auritus	Hivoondroo river	27	" 22 "	Iris, *dark brown;* beak, *bright yellow;* feet, *black.*
612	Shrike	Vanga	Vanga curvirostris	Feneriffe	28	" 19 "	Iris, *brown;* beak, *black;* legs, *lead colour.*
613	Paroquette	... ...	Poliopsitta cana	Tamatave	29	" 11 "	Killed 19 at one shot.
614	Starling	Veron tinombi	Hartlaubia madagascariensis	Soumandrakasi	30*		
615	Quail	Kiboo	Turnix nigricollis	Soumandrakasi	31	" 23 "	
616	Sandpiper	Kibooranto	Tringoides hypoleucus	Hivoondroo river	32	" 23 "	
617	... ...	Todiah	Gervaisia albo specularis	Ambouedimond	33	" 25 "	Iris, *brown;* beak, *black;* legs, *dusky grey.*
618	... ...	Tashu	Coua cærulea	Chasmamia	34	Oct. 1 "	Iris, *dark brown;* skin round eye, *blue;* beak and legs, *black.*
619	... ...	Veron kaif	Eurystomus madagascariensis	... ...	35	...	Shot during the journey to the Capital on the first expedition to Madagascar under Lt.-Col. Middleton, R.A. C.B.,
620	Pigeon	... ...	Funingus madagascariensis	... ...	36	...	
621	... ...	Chikoza	Canirallus kioloides	... ...	37	...	
622	Water hen	... ...	Porphyrio madagascariensis	... ...	38	...	
623	Snipe	Rara rar	Gallinago bernieri	... ...	39	...	* Denotes in duplicate.

Geological Specimens from the Yang-tse-Kiang, presented by Captain Blakiston, R.A.

No.	Description.	Locality.	Date.
1	Sandstone and felstone	Chin-kiang	Feb. 20, 61
2	Red sandstone	Nanking	„ 26 „
3	Quartz rock	Between Hankow and Kingkow, left bank	June 28 „
4	Pinkish limestone	Opposite Chi-kiang	Mar. 30 „
5	Pebbles of quartz, jaspar, and limestone from conglomerate	Near I-chang	Apr. 1 „
6	Calcareous sandstone	Opposite I-chang	„ 4 „
7	Limestone, and ribboned silicious rock and grit, or chert	Six miles above I-chang	„ 5 „
8	Granite, in boulders	Seven miles N.W. of I-chang	do
9	Gneiss	Below Lu-kan gorge	„ 7 „
10	Sandstone, with green grains	Five miles below Kwei	„ 8 „
11	Purple marly sandstone, and silicious grit	Kwei	do
12	Inferior coal, and rock-like under clay	Near Kwei	do
13	Sandstone, with exposed surface glossed	Near coal, two miles west of Kwei ...	June 14 „
14	Limestone (fine-grained)	Village of Kwan-du-kow	Apr. 9 „
15	Blackish limestone (very hard)	In Wu-shan gorge, at the boundary between Hoo-peh and Sz'chuan provinces	„ 10 „
16	Dark grey limestone, with veins of calcareous spar	Quai-chow (foo)	June 13 „
17	Coal (anthracite)	Between Quai-chow and Yung-yan ...	Apr. 14 „
18	Silicious sand, with spangles of white and yellow mica, iron, and small grains of gold	Bed of the Yang-tse near Wan (hien)	Apr. 16 „
19	Rough calcareous sandstone	In blocks along the river near Wan ...	do
20	Lime, probably calcined, and which has afterwards, by exposure, re-absorbed carbonic acid	Used for cement at Wan	do
21	Grey sandstone	Near Fung-tu	„ 23 „
22	„ „	From a reef at Fu	„ 24 „
23	Grey micaceous and felspathic sandstones	Below Chung-king	„ 27 „
24	Slag	Below Chung-king. Supposed from an iron-smelting furnace	do
25	Same as 21, with fragments of sandstone and limestone	Range of hills east of Chung-king, where coal is worked	June 7 „
26	Hard silicious grit	Above Chung-king	May 4 „
27	Soft micaceous and silicious grit	„ „	do
28	Fine red calcareous sandstone	Near Kin-tin-tse Island	do
29	Sandstone	Near village of Chung-pa-sha	„ 7 „
30	Micaceous sandstone	Na-chi	„ 14 „
31	Limestone, and red and grey sandstone	Opposite Nan-ki	„ 17 „
32	Bituminous coal, carbonaceous shale, and grey shale	Mines of Pa-ko-shan, below Su-chow	„ 18
33	Dark purple micaceous sandstone	Su-chow	„ 21
34	Bituminous coal and sandstone	Ta-tan-pa Rapid, above Su-chow	„ 24 „

Fish, presented by Sir J. Richardson.

Sargus rondelalii.
„ saluani.
Julis pavo.
„ vulgaris.
Dentex vulgaris.

Serranus scriba.
Scorpœna porcus.
Pagrus harter.
Mullus ———
Gobius ———

APPENDIX II.

LIST OF SERVICE PROJECTILES, &c. PRESENTED TO THE INSTITUTION, BY H.M. GOVERNMENT.

Articles.	Whole.	Sections.
Adapters, brass	1	1
Balls — light ground, filled in imitation — 10-in.	1	1
Balls — light ground, filled in imitation — 8 „	1	1
Balls — light ground, filled in imitation — 5½ „	1	1
Balls — light ground, filled in imitation — 4⅖ „	1	1
Balls — smoke, 13-in. — empty	1	...
Balls — smoke, 13-in. — filled in imitation	1	1
Balls — light parachute Boxer's 10-in.	1	3
Boxes, mahogany	7	...
Bursters, empty — iron — 20-pr. O. P.	1	1
Bursters, empty — iron — 20-pr. N. P.	1	2
Bursters, empty — iron — 12 „ „	1	2
Bursters, empty — iron — 9 „ „	1	1
Bursters, empty — tin ... 6 „ „	1	1
Caps — percussion — finished	55	...
Caps — percussion — unfinished	66	...
Caps — metal fuze	3	...
Carcasses filled in imitation — loose — 13-inch	1	1
Carcasses filled in imitation — loose — 10 „	1	1
Carcasses filled in imitation — loose — 8 „	1	1
Carcasses filled in imitation — loose — 5½ „	1	1
Carcasses filled in imitation — loose — 4⅖ „	1	1
Carcasses filled in imitation — loose — 32-pr.	1	1
Carcasses filled in imitation — riveted to bottoms — 5½-in.	1	1
Carcasses filled in imitation — riveted to bottoms — 4⅖ „	1	1
Carcasses filled in imitation — riveted to bottoms — 24-pr.	1	1
Carcasses filled in imitation — riveted to bottoms — 12 „	1	1
Cartridges:— bursters, calico, empty, with paper covers — Armstrong — com. 40-pr. 2½ lb.	1	...
Cartridges:— bursters, calico, empty, with paper covers — Armstrong — seg. 40 „ 10 oz.	1	...
Cartridges:— bursters, calico, empty, with paper covers — smooth bore — com. 10-in. 5 lb.	1	...
Cartridges:— bursters, calico, empty, with paper covers — smooth bore — diaph. 6-pr. 10 dr.	1	...
Cartridges:— bursters, calico, empty, with paper covers, and water-proof bags — Armstrong — com. 110 „ 8 lb.	1	...
Cartridges:— bursters, calico, empty, with paper covers, and water-proof bags — Armstrong — com. 20 „ 1 „	1	...
Cartridges:— bursters, calico, empty, with paper covers, and water-proof bags — Armstrong — seg. 110 „ 3 „	1	...
Cartridges:— bursters, calico, empty, with paper covers, and water-proof bags — Armstrong — seg. 40 „ 10 oz.	1	...
Cartridges:— bursters, calico, empty, with paper covers, and water-proof bags — smooth bore — common — 10-in. 6¼ lb.	1	...
Cartridges:— bursters, calico, empty, with paper covers, and water-proof bags — smooth bore — common — 8 „ 2¼ „	1	...
Cartridges:— bursters, calico, empty, with paper covers, and water-proof bags — smooth bore — common — 42-pr. 1 5/16 „	1	...
Cartridges:— bursters, calico, empty, with paper covers, and water-proof bags — smooth bore — common — 32 „ 1 3/16 „	1	...
Cartridges:— bursters, calico, empty, with paper covers, and water-proof bags — smooth bore — common — 24 „ 13 oz.	1	...
Cartridges:— bursters, calico, empty, with paper covers, and water-proof bags — smooth bore — common — 18 „ 10 „	1	...
Cartridges:— bursters, calico, empty, with paper covers, and water-proof bags — smooth bore — common — 12 „ 6 „	1	...
Cartridges:— bursters, calico, empty, with paper covers, and water-proof bags — smooth bore — diaph. — 8-in. 60 dr.	1	...
Cartridges:— bursters, calico, empty, with paper covers, and water-proof bags — smooth bore — diaph. — 56-pr. 55 „	1	...
Cartridges:— bursters, calico, empty, with paper covers, and water-proof bags — smooth bore — diaph. — 42 „ 50 „	1	...
Cartridges:— bursters, calico, empty, with paper covers, and water-proof bags — smooth bore — diaph. — 32 „ 40 „	1	...
Cartridges:— bursters, calico, empty, with paper covers, and water-proof bags — smooth bore — diaph. — 24 „ 30 „	1	...
Cartridges:— bursters, calico, empty, with paper covers, and water-proof bags — smooth bore — diaph. — 18 „ 25 „	1	...
Cartridges:— bursters, calico, empty, with paper covers, and water-proof bags — smooth bore — diaph. — 12 „ 20 „	1	...
Cartridges:— bursters, calico, empty, with paper covers, and water-proof bags — smooth bore — diaph. — 9 „ 15 „	1	...
Cartridges, flannel, empty — bags for spare powder, 15 lb.	1	...
Cartridges, flannel, empty — Armstrong 12-pr. 1½ lb.	1	...
Cartridges:— flannel, empty, with water-proof bags, and paper covers — Armstrong gun — 110-pr. 12 lb.	1	...
Cartridges:— flannel, empty, with water-proof bags, and paper covers — Armstrong gun — 40 „ 5 lb. L. S.	1	...
Cartridges:— flannel, empty, with water-proof bags, and paper covers — Armstrong gun — 40 „ 5 lb. S. S.	1	...
Cartridges:— flannel, empty, with water-proof bags, and paper covers — Armstrong gun — 20 „ 2½ lb.	1	...
Cartridges:— flannel, empty, with water-proof bags, and paper covers — Armstrong gun — 12 „ 1½ „	1	...
Cartridges:— flannel, empty, with water-proof bags, and paper covers — Armstrong gun — 9 „ 1 3/16 „	1	...
Cartridges:— flannel, empty, with water-proof bags, and paper covers — Armstrong gun — 6 „ 12 oz.	1	...
Cartridges:— flannel, empty, with water-proof bags, and paper covers — Armstrong gun — 9 or 12-pr. 1 lb.	1	...
Cartridges:— flannel, empty, with water-proof bags, and paper covers — smooth bore — carronade — 68-pr. 5 lb.	1	...
Cartridges:— flannel, empty, with water-proof bags, and paper covers — smooth bore — carronade — 42 „ 3½ „	1	...
Cartridges:— flannel, empty, with water-proof bags, and paper covers — smooth bore — carronade — 32 „ 2 11/16 „	1	...
Cartridges:— flannel, empty, with water-proof bags, and paper covers — smooth bore — carronade — 24 „ 2 „	1	...
Cartridges:— flannel, empty, with water-proof bags, and paper covers — smooth bore — carronade — 18 „ 1½ „	1	...
Cartridges:— flannel, empty, with water-proof bags, and paper covers — smooth bore — carronade — 12 „ 1 „	1	...
Cartridges:— flannel, empty, with water-proof bags, and paper covers — smooth bore — carronade — 6 „ 10 oz.	1	...
Cartridges:— flannel, empty, with water-proof bags, and paper covers — smooth bore — gun — 10-in. 12 lb.	1	...
Cartridges:— flannel, empty, with water-proof bags, and paper covers — smooth bore — gun — 56-pr. 14 „	1	...
Cartridges:— flannel, empty, with water-proof bags, and paper covers — smooth bore — gun — 42 „ 14 „	1	...
Cartridges:— flannel, empty, with water-proof bags, and paper covers — smooth bore — gun — 32 „ 10 „	1	...
Cartridges:— flannel, empty, with water-proof bags, and paper covers — smooth bore — gun — 24 „ 8 „	1	...
Cartridges:— flannel, empty, with water-proof bags, and paper covers — smooth bore — gun — 18 „ 6 „	1	...
Cartridges:— flannel, empty, with water-proof bags, and paper covers — smooth bore — gun — 12 „ 4 „	1	...
Cartridges:— flannel, empty, with water-proof bags, and paper covers — smooth bore — gun — 9 „ 3 lb.	1	...
Cartridges:— flannel, empty, with water-proof bags, and paper covers — smooth bore — gun — 9 „ 2½ „	1	...
Cartridges:— flannel, empty, with water-proof bags, and paper covers — smooth bore — gun — 6 „ 2 „	1	...
Cartridges:— flannel, empty, with water-proof bags, and paper covers — smooth bore — gun — 3 „ 12 oz.	1	...
Cartridges:— flannel, empty, with water-proof bags, and paper covers — smooth bore — howitzer, S. B. — 10-in. 7 lb.	1	...
Cartridges:— flannel, empty, with water-proof bags, and paper covers — smooth bore — howitzer, S. B. — 8 „ 4 „	1	...
Cartridges:— flannel, empty, with water-proof bags, and paper covers — smooth bore — howitzer, S. B. — 5½ „ 2 „	1	...
Cartridges:— flannel, empty, with water-proof bags, and paper covers — smooth bore — howitzer, S. B. — 4⅖ „ 8 oz.	1	...
Cartridges:— flannel, empty, with water-proof bags, and paper covers — smooth bore — howitzer, S. B. — 32-pr. 3 lb.	1	...
Cartridges:— flannel, empty, with water-proof bags, and paper covers — smooth bore — howitzer, S. B. — 24 „ 2½ „	1	...
Cartridges:— flannel, empty, with water-proof bags, and paper covers — smooth bore — howitzer, S. B. — 12 „ 2 „	1	...
Cartridges:— filled with coal dust — bursters, calico, for shells — Armstrong 40-pr. — common 2½ lb.	1	...
Cartridges:— filled with coal dust — bursters, calico, for shells — Armstrong 40-pr. — segment 10 oz.	1	...
Cartridges:— filled with coal dust — bursters, calico, for shells — smooth bore — com. 10-in. 5 lb.	1	...
Cartridges:— filled with coal dust — bursters, calico, for shells — smooth bore — diaph. 6-pr. 10 dr.	1	...
Cartridges:— filled with coal dust — flannel — Armstrong gun. — for Boxer's lubricator... 110-pr. 12 lb.	1	...
Cartridges:— filled with coal dust — flannel — Armstrong gun. — with Boxer's lubricator ... 12-pr. 1½ lbs.	1	...
Cartridges:— filled with coal dust — flannel — smooth bore — gun 68-pr. 16 lb.	1	...
Cartridges:— filled with coal dust — flannel — smooth bore — gun 6 „ 1½ „	1	...
Cartridges:— filled with coal dust — flannel — smooth bore — howitzer, 12-pr. 1¼ lb.	1	...
Cartridges:— filled with coal dust — flannel — smooth bore — mortar, 13-in. 20 lb.	1	...
Cartridges:— filled with coal dust — flannel, in water-proof bags and paper covers — Armstrong — for Boxer's lubricator... 110-pr. 12 lb.	1	...
Cartridges:— filled with coal dust — flannel, in water-proof bags and paper covers — Armstrong — with bursters lubric. L. S. 40-pr. 5 lb.	1	...
Cartridges:— filled with coal dust — flannel, in water-proof bags and paper covers — Armstrong — with do 20-pr. 2½ lb.	1	...
Cartridges:— filled with coal dust — flannel, in water-proof bags and paper covers — Armstrong — do 12-pr. 1½ „	1	...
Cartridges:— filled with coal dust — flannel, in water-proof bags and paper covers — Armstrong — with saw-dust wads 9 or 12-pr. 1 lb.	1	...
Cartridges:— filled with coal dust — gun, s. bore, L.S. 8-in. 10 lb.	1	...

Articles.	Whole.	Sections.	Parts.
Cartridges:—			
S. A. percussion, filled with coal-dust, ball, carbine, breech-loading, Artillery rifle 2 dr.	11	...	4
„ „ Shrapnel ... 2¼ „	11	...	5
„ „ Perry's ...... 2 „	11	...	6
„ „ W. Richard's 2 „	11	...	7
„ ball, Colt's revolvers	73	...	3
„ ball, rifle musket, 42, 2¾ dr.	11	...	4
„ „ 51, 2½ „	11	...	4
„ „ 53, 2½ „	11	...	4
„ ball, Whitworth's rifle, 2½ dr.	11	...	4
„ blank, all arms, 3½ dr.	11	...	1
Cylinders, zinc	1	...	...
Diagrams, lithograph, of sorts, mounted, set	1	...	...
Fuzes, metal, Armstrong, concussion	1	...	...
„ percussion, F. S.	1	1	...
„ pillar	1	3	...
„ time ... O. P.	1	4	...
„ time ... E. ...	1	4	...
Fuzes, metal, Boxer's, time ...... 20 secs.	1	2	...
„ 7½ „	1	2	...
Fuzes, metal, Moorsom's	1	2	...
Fuzes, metal, Pettman's ...... L. S.	1	2	...
„ S. S.	1	5	...
Fuzes, service, Boxer's, common	1	1	...
„ diaphragm	1	7	...
„ mortar 13, 10·8-in.	1	12	...
„ mortar 5½, 4⅖ „	1	4	...
„ for Manby's shot ...	1	3	...
„ „ parachute light	5	3	...
„ shrapnel improved	...	1	...
Fuzes, service, Behenna's for firing rockets, 24-pr.	1	10	...
„ 12 „	1	...	...
„ 6 „	1	...	...
„ 3 „	1	...	...
Fuzes, service, hand grenade ...	1	...	...
Fuzes, service, rocket, 24-pr.	1	1	...
Fuzes, mortar, 3-in. graduated	1	1	...
Fuzes, obsolete wood, common, 13-in.	1	1	...
„ 10 „	1	1	...
„ 8 „	1	...	...
„ 5½ „	1	...	...
„ 4⅖ „	1	...	...
Fuzes, obsolete wood, Freeburn's	1	...	...
Fuzes, obsolete wood, hand grenade ...	1	1	...
Fuzes, obsolete wood, 8-in. uncut ...	1	1	...
„ 8-in. cut to 1 in.	1	...	...
Fuzes, obsolete wood, spherical, 5½-in. cut ... a	...	2	...
„ b	1	...	...
„ c	1	...	...
„ d	1	...	...
„ e	1	...	...
„ f	1	...	...
„ g	1	...	...
„ 1 in.	1	...	...
„ 5½-in. uncut	1	5	...
Handles for percussion lights	1	...	...
Implements, fuze and shell, bits, fuze, gun, long	7	...	...
„ „ short	8	...	...
„ mortar	1	...	...
„ braces for fuzes, mortar	1	...	...
„ „ naval	1	...	...
„ borers ... hand	1	...	...
„ „ hook	1	...	...
„ cylinders, wood	1	...	...
„ key, iron plug	1	...	...
„ do naval „	1	...	...
„ do shell and fuze	1	...	...
Lights, blue	1	1	...

Articles.	Whole.	Sections.	Parts.
Lights, percussion ... long ...	1	1	...
„ signal ...	1	1	...
Lubricators, Boxer's, for Armstrong cartridge, 110-pr.	1	...	...
do do 12 or 9-pr.	1	...	...
Plugs, shell, brass ... common	13	...	...
„ diaphragm	11	...	...
„ Martin's	2	...	...
„ naval	1	...	...
„ shrapnel, improved	9	...	...
Plugs, shell, brass, naval	6	...	...
Plugs, shell, metal	3	...	...
Portfires, common	1	1	...
„ percussion	1	1	...
Rockets, signal, filled in imitation, 1 lb.	1	1	...
„ ½ „	1	1	...
Rockets, war, filled in imitation .... shell, 24-pr.	1	1	...
„ 12 „	1	1	...
„ 6 „	1	1	...
„ 3 „	1	1	...

Articles.	Whole filled with ball.	Whole empty.	Sections filled in imitation.	Sections filled with ball.	Sections empty.
Shells, smooth bore, riveted to wood bottoms, common, adapted for Pettman's L. S. fuze, 10-in. ...	...	1	1	...	...
„ 8 „ or 68-pr.	...	1	1	...	...
„ 5½-in. ...	...	1	1	...	...
„ 4⅖ „ ...	...	1	1	...	...
„ 56-pr. ..	...	1	1	...	...
„ 42 „ ...	...	1	1	...	...
„ 32 „ ...	...	1	1	...	...
„ 24 „ ...	...	1	1	...	...
„ 18 „ ...	...	1	1	...	...
„ 12 „ ...	...	1	1	...	...
„ diaphragm. 58-pr., gun or howitzer, 8-in. ...	1	...	...	1	1
„ 32-pr. ...	1	...	...	1	1
„ 24 „ ...	1	...	...	1	1
„ 12 „ ...	1	...	...	1	1
„ gun ... 56 „ ...	1	...	...	1	1
„ 42 „ ...	1	...	...	1	1
„ 18 „ ...	1	...	...	1	1
„ 9 „ ...	1	...	...	1	1
„ 6 „ ...	1	...	...	1	1
„ howitzer, 5½-in. ...	1	...	...	1	1
„ 4⅖ „ ...	1	...	...	1	1
„ Martin's ... 10 „ ...	...	1	1	...	...
„ 8 „ ...	...	1	1	...	...
Shells, smooth bore, loose, mortar prepared for fuzes, corked, 13 „ ...	...	1	1	...	...
„ 10 „ ...	...	1	1	...	...
„ 8 „ ...	...	1	1	...	...
„ plugged, 5½-in.	1	1	...	...	...
„ 4⅖ „	1	1	...	...	...
„ naval, riveted to wood bottoms, 10-in	1	1	...	...	...
„ 8 „ or 68-pr.	1	1	...	...	...
„ 32 „	1	1	...	...	...

Articles.	Whole.	Sections.	Parts.
Shells, smooth bore, shrapnel, improved, riveted to wood bottoms, 8-in.	1	1	...
" 5½ ,,	1	1	...
" 4⅖ ,,	1	1	...
" 32-pr.	1	1	...
" 24 ,,	1	1	...
" 18 ,,	1	1	...
" 12 ,,	1	1	...
" 9 ,,	1	1	...
" 6 ,,	1	1	...
Shells, smooth bore, shrapnel, O. P., strapped to wood bottoms, 8-in.	1	1	...
" 32-pr.	1	1	...
" 24 ,,	1	1	...
" 18 ,,	1	1	...
" 12 ,,	1	1	...
" 9 ,,	1	1	...
" 6 ,,	1	1	...
Shells, L. M. .... common, 110 ,,	1	1	...
" 40 ,,	1	1	...
" 20 ,,	1	1	...
Shells, L. M., segment, 110 ,,	1	1	...
" 40 ,,	1	1	...
" 20 ,,	1	1	...
" 12 ,,	1	1	...
" 6 ,,	1	...	...
Shot, case, gun, with iron ends, 10-in.	1	...	...
" 8 ,, or 68-pr	1	...	...
" 56-pr.	1	...	...
" 42 ,, ...	1	...	...
" 32 ,, ...	1	...	...
" 24 ,, ...	1	...	...
" 18 ,, ...	1	...	...
Shot, case, gun, with wood bottoms, 12 ,, ...	1	...	...
" 9 ,, ...	1	...	...
" 6 ,, ...	1	...	...
" 3 ,, ...	1	...	...
Shot, case, howitzer, L. S., with iron ends, 10-in.	1	...	...
" 8 ,,	1	...	...
Shot, case, howitzer, L. S., with wood bottoms, 5½ ,,	1	...	...
" 4⅖ ,,	1	...	...
" 32-pr.	1	...	...
" 24 ,,	1	...	...
" 12 ,,	1	...	...
Shot, case, howitzer, S. S., with wood bottoms, 24 ,,	1	...	...
" 12 ,,	1	...	...
Shot, case, carronade .... 68 ,,	1	1	...
" 42 ,,	1	...	...
" 32 ,,	1	...	...
" 24 ,,	1	...	...
" 18 ,,	1	...	...
" 12 ,,	1	...	...
" 6 ,,	1	...	...
Shot, grape, carronade ...... 68-pr.	1	...	...
" 42 ,, ...	1	...	...
" 32 ,, ...	1	...	...
" 24 ,, ...	1	...	...
" 18 ,, ...	1	...	...
" 12 ,, ...	1	...	...
" 6 ,, ...	1	...	...
Shot, grape, gun, common, 10-in.	1	...	...
" 8 ,, or 68-pr	nil	...	...
Shot, grape, gun, Caffin's, 8-in. or 68-pr	1	...	...
" 56-pr.	1	...	...
" 42 ,, ...	1	...	...

Articles.	Whole.	Sections.	Parts.
Shot, grape, gun, Caffin's, 32-pr.	1	...	...
" 24 ,, ...	1	...	...
" 18 ,, ...	1	...	...
" 12 ,, ...	1	...	...
" 9 ,, ...	1	...	...
" 6 ,, ...	1	...	...
" in. tin case 3-pr....	1	...	...
Shot, solid, loose........................ 68-pr.	1	...	...
" 56 ,,	1	...	...
" 42 ,,	1	...	...
" 32 ,,	1	...	...
" 24 ,,	1	...	...
Shot, solid, L. M. .... 110 ,,	1	...	...
" 40 ,,	1	...	...
" 20 ,,	1	...	...
" 12 ,,	1	...	...
" 9 ,,	1	...	...
" 6 ,,	1	...	...
Shot, solid, riveted, gun.................. 18 ,,	1	...	...
" 9 ,,	1	...	...
" 6 ,,	1	...	...
" 3 ,,	1	...	...
Shot, solid, riveted, gun and howitzer......12 ,,	1	...	...
Shot, Manby's, whole, looped, thonged, and prepared for fuzes.	1	...	...
Shot, Manby's, section	1	...	...
Shot, sand.............................. 4 lbs. ...	1	...	...
" 3 ,, ...	1	...	...
" 2 ,, ...	1	...	...
" 1½ ,, ...	1	...	...
" 1 ,, ...	1	...	...
" 13⅛ oz. ...	1	...	...
" 8 ,, ...	1	...	...
" 6½ ,, ...	1	...	...
" 6 ,, ...	1	...	...
" 5 ,, ...	1	...	...
" 4 ,, ...	1	...	...
" 3¼ ,, ...	1	...	...
" 3 ,, ...	1	...	...
" 2 ,, ...	1	...	...
" 1½ ,, ...	1	...	...
Skeletons, for ground light balls ... 10-in....	1	...	...
" 8 ,, ...	1	...	...
" 5½ ,, ...	1	...	...
" 4⅖ ,, ...	1	...	...
Stands, wood, shot and shell	128	...	...
Sticks, rocket, war .... 24-pr....	1	...	...
" 12 ,, ...	1	...	...
" 6 ,, ...	1	...	...
" 3 ,, ...	1	...	...
Sticks, rocket, signal .... 1 lb....	1	...	...
" ½ ,, ...	1	...	...
Tubes .... brass	1	1	3
" friction, copper	1	1	4
" friction, quill...	1	1	7
" galvanic..........	1	1	3
" magnetic	1	2	3
" paper, dutch......	1	1	3
" quill... +headed	1	1	5
" quill... common	1	...	5
" quill... match...	1	...	2
" war rocket........	1	1	2

LIST OF MEMBERS

OF THE

ROYAL ARTILLERY INSTITUTION, WOOLWICH.

[ARRANGED ALPHABETICALLY.]

MAY, 1863.

COLONEL.

FIELD MARSHAL H.R.H. THE DUKE OF CAMBRIDGE, K.G.

COLONELS COMMANDANT.

Campbell, Frederick, *g*
Cator, William, C.B. *l.g*
Cobbe, George, *l.g*
Colebrooke, Sir W. M. C.B., K.H. *l.g*
Gardiner, Sir R. W. 𝔚 G.C.B., K.C.H. *g*
Gordon, Henry W. *m.g*
Jones, Richard, *l.g*
Mercer, Alex. C. 𝔚 *l.g*
Michell, Sir John, K.C.B., *l.g*
Ross, Sir Hew D. 𝔚 G.C.B. *g*
Scott, Henry Alexander, *l.g*
Turner, Sir Geo. K.C.B. *g*
Wallace, Peter M. *g*
Whinyates, Sir E. C. 𝔚 K.C.B., K.H. *l.g*
Wylde, William, C.B. *l.g*

GENERAL OFFICERS.

Abbott, A. C.B. *m.g*
Anderson, W. C. 𝔚 *m.g*
Arbuckle, B. H. V. *m.g*
Armstrong R. S. *m.g*
Bell, W. 𝔚 *m.g*
Belson, G. J. *m.g*
Blachley, H. *m.g*
Bloomfield, J. 𝔚 *m.g. Ins-Gen.*
Brereton, Sir W. K.C.B., K.H. *m.g*
Cator, T. O. *m.g*
Chesney, F. R. *m.g*
Dacres, Sir R. J. K.C.B., *m.g*
Dalton, C. *m.g*
Dunn, W. *m.g*
England, P. V. *m.g*
Eyre, J. *m.g*
Fogo, J. *m.g*
Freer, J. H. *m.g*
Gordon, J. *m.g*
Grant, D. *m.g*
Hanwell, J. *m.g*
Hardinge, R. 𝔚 K.H. *m.g*
Higgins, T. Gordon, *m.g*
Hope, A. W. *m.g*
Ingilby, W. B. 𝔚 *m.g*
Maclachlan, A. *l.g*
Morris, H. G. *m.g*
Palliser, H. *m.g*
Pester, Henry, *m.g*
Romer, R. F.
Sabine, E. *m.g*
Tuite, H. M. *m.g*
Warde, F. 𝔚 *m.g*
Williams, Sir W. F. Bart, K.C.B. *m.g*
Willis, Browne, *m.g*

COLONELS.

Abbott, James
Askwith, William H.
Aylmer, Henry
Beresford, G. J.
Bingham, C., *Dep.-Adjt.-Gen.*
Buchanan, G. J. L.
Burn, Robert
Cockburn, Charles V.
Crawford, R. Fitzgerald
Crofton, E. W. C.B.
Cuppage, Burke 𝔚
Dalton, Charles J.
Dick, Francis
Dunlop, Franklin C.B.

Eardley-Wilmot, F. M.
Fitzmayer, J. W. C.B.
Flude, Thomas Peters
Foster, H.
Francklyn, J. H. C.B.
Freese, J. N. A. C.B.
Gambier, G. C.B.
Grant, E. F.
Hamilton, F. S.
Hogge, C. C.B.
Irving, Alexander, C.B
Kennedy, G. R. H.
Lake, N. T. C.B.
M'Coy, John
Mee, C. H.
Nedham, William Robert
Ormsby, John William
Rowan, Henry S. C.B.
Sandham, G.
Simpson, G. W. Y.
Spencer, Hon. R. C. H.
St George, J. C.B., *b.g*
Stopford-Blair, W. H.
Stow, H.
Symons, Charles Bertie
Taylor, Arthur Joseph
Teesdale, Henry G.
Thorndike, Daniel
Tulloh, Alexander, *m.g*
Turner, Henry Austin
Tylee, A.
Warde, E. C. C.B.
Wilford, Edmund Neal
Wingfield, C. W.
Wood, Sir D. E. K.C.B.
Wragge, J.

LIEUTENANT-COLONELS.

Adye, John M. C.B. *c*
Anderson, J. R. C.B.
Barrow, J. Lyon
Benn, Anthony, *c*
Bond, F. W.
Boxer, E. Mourrier
Brougham, Thomas
Broughton, S. D.
Burrows, Arthur George, *c*
Cadell, Alexander Todd
Campbell, Fred. Alex. *c*
Campbell, H. A. B. C.B. *c*
Carleton, H. A. C.B
Childs, Joseph Clarke
Christie, H. Paget, *c*
Clerk, Henry
Clifford, Miller
Connell, Adolphus Fred.
Cox, W. Hamilton
Crofton, Richard Henry
D'Aguilar, C. L. C.B. *c*
Dennis, James Benjamin, *c*
De Rinzy, G. A. F. *c*
De Teissier, H. Price
Devereux, Hon. G. T. *c*
Dickson, VC C. C.B. *c*
Dixon, W. M. Hall, *c*
Dixon, VC Matthew Charles, *c*
Domville, James Wm. *c*
Du Plat, Charles Taylor
Elwyn, Thomas, *c*
Fisher, Edward Henry
Franklin, C. T. C.B.
Gardiner, H. L.
Gardner, William Bethel, *c*
Gibbard, Henry Lee
Gibbon, James R. C.B.
Gilbert, W. R.
Goodenough, H. Philip, *c*
Graydon, George, *c*
Graham, Allan Hamilton, *c*
Grant, W. J. Esten
Green, Andrew Pellet
Hamilton, A. G. W.
Hatch, W. S.
Haultain, F. W.
Hawkins, A. Cæsar
Henderson, William, *c*
Hutchinson, C. H.
Inglefield, J. H. S.
Johnson, George V.
Kemball, A. B.
Knox, Thomas
Lefroy, John Henry, *c*
Longden, C. Scudamore
Maberly, Evan, C.B. *c*
Mackay, Neil M'Innes.
Maude, G. A. C.B.
Maxwell, William,
M'Crea, R. Barlow
Maclean, Peter, *c*
Marriott, T. B. Feilding, *c*
Middleton, W. A. C.B.
Morgan, E.
Mountain, Robert F.
Mundy, Pierrepont H. *c*
Nixon, Murray Octavius
O'Connell, Richard
Paynter, D. W. C.B. *c*

Phillpotts, A. T. *c*
Price, Edward, C.B. *c*
Radcliffe, Robert Parker
Riddell, C. J. B. C.B. *c.*
Romer, R. Corcyra
Selby, G.
Shakespear, G. B. *c*
Smyth, J. Hall, C.B.
Smythe, William James, *c*
Strange, H. F. C.B. *c*
Talbot, Robert
Thompson, Arnold
Travers, John, *c*
Travers, Frederick J.
Turner, John, C.B. *c*
Voyle, G. E.
Ward, Francis Beckford
Williams, E. A.
Wodehouse, E. C.B. *c. Asst.-adj.-gen. A.D.C. to the Queen*
Woosman, James Bowen
Worgan, John
Wright, Charles James, *c*
Younghusband, C. W.

CAPTAINS.

Adams, John A. P.
Addington, Hon. L. A.
Alderson, Henry J.
Anderson, James H. P.
Andrews, William G. *m*
Anley, Fred. Augustus
Anson, A. E. Harbord
Arbuthnot, Charles G. *m*
Arbuthnot, H. T. *m*
Arbuckle, C. V.
Archdale, A. M.
Atlay, Edward
Balfour, Henry Lowther
Barnett, William Townsend
Barry, W. Wigram C.B., *l.c*
Barstow, George, *l.c*
Barton, James, *adjt.*
Barton, C. J.
Baylay, Frederick George, *adjt.*
Bayly, Neville S. Keats
Bayly, A. A.
Bazalgette, Sydney Augustus
Bedingfeld, Philip, *m*
Bent, Hugh
Beresford, D. W. Pack
Berthon, J. P.
Betty, Joshua F.
Bevan, C. Donnithorne
Biddulph, M. A. S. *l.c*
Biddulph, Robert, *m*
Bishop, H. Parlett, *m*
Blackburn, H. B.
Blackwell, James Edward
Blakely, A. T.
Blakiston, T. W.
Blosse, W. C. L.
Bolton, John Lawrence
Bolton, William John, *m*
Bolton, Edward Chichester
Booth, William
Boothby, John George, *l.c*
Bowie, C. Vincent, *l.c*
Boyle, Robert
Brackenbury, C. Booth
Bredin, Edgar G.
Brendon, Algernon, *m*
Briscoe, Henry Whitby
Brown, John. T. B.
Brown, John Henry
Browne, Charles Orde
Bruce, Edward Jackson
Burnaby, Alex. Dickson
Burt, Charles E. *m*
Byrne, Thomas E.
Cairnes, Robert J. *adjt.*
Calvert, A. M.
Campbell, Robert. C. W.
Campbell, Sir J. W. Bart.
Campbell, John M'C. *m*
Campbell, Patrick J.
Campbell, J. *m*
Cardew, Henry
Carey, Thomas Priaulx
Carey, William, *adjt.*
Carey, Falkland
Carleton, George
Carpenter, Charles
Carr, Oswald
Carthew, Edmund J. *m*
Champion, R. H. *m*
Chancellor, Frederick Hugh
Chandler, George Lee, *m*
Chermside, Henry L. *l.c*
Clarke, John Lardner
Close, Frederick
Cockburn, Charles F.
Colclough, George
Collington, John W. *adjt.*
Collingwood, Clennell
Colomb, George Hatton
Conybeare, Frederick

Craufurd, R. E. F. *m*
Crawford, George Adam
Cromartie, Frederick Nurse
Cuming, Thomas
Curtis, Reginald, *m*
Dadson, J. N. P. *adjt.*
Dames, Thomas Longworth
Davis, Gronow, VC *m*
Daubuz, John T.
De Havilland, James, *m*
De Moleyns, T. A.
Denne, Lambert H.
Desborough, John, *l.c*
De Vismes, Henry A. D.
De Winton, Francis Walter
Dickson, Philip, *m*
Dirom, Thomas Alexander
Downes, Major F. *adjt.*
Doyne, Henry Archdall
Drayson, Alfred Wilks
Dumaresq, W. Lovelace
Dyer, Henry Clement S.
Eden, Morton Parker, *adjt.*
Elgee, J. Lindredge, *m*
Elgee, Cadwalleder William
Elliot, Henry Sheridan
Ellis, Wilmot Burrows, E.
Elton, Fred. Coulthurst
Evans, Charles R. Ogden, *m*
Eveleigh, J. E.
Everett, James
Fenwick, W. Y. *m*
Farmer, R. Onslow
Farrell. Henry C.
Field, Thomas Samuel Poer, *m*
Field, George Thomas, *m.*
FitzHugh, H. T. *m*
Fitzmaurice, Maurice H. *adjt.*
Forbes, G. H. A.
Forde, Matthew Bligh
Franklen, Charles R.
Fraser, George Henry J. A.
Fraser, Hon. D. M. *l.c*
Freeling, Sandford
Freeth, Richard King
French, William
Frith, J. S. *m*
Gabbett, Robert Poole
Gage, Hon. E. T. *l.c*
Geary, Henry Le Guay *adjt.*
Gilmour, Charles D.
Glanville, Francis Robert
Gleig, Alex. Cameron, *m*
Godby, Joseph, *m*
Goodenough, W. H. *m.*
Goodenough, O. H.
Gordon, Samuel E. *l.c*
Gore, J. *m*
Gore, Ralph
Gossett, A. *m*
Govan, Charles Maitland, *m*
Greene, D. Sarsfield, *m*
Greville, H. Lambert F.
Griffin, Frederick Cockburn
Griffiths, F. A. *m*
Griffiths, Leonard
Grimston, Walter John
Grylls, S. M. *m*
Haig, Robert Wolseley
Holcombe, F. *m*
Hall, Wm. James
Hall, Lewis Frederick
Hamilton, Sir W., Bart.
Hamilton, Augustus H. C.
Hamley, Bruce E. *l.c*
Hanwell, Joseph, *adjt.*
Hardy, Campbell
Harris, Noel Hawlyn
Harrison, Thomas A. J.
Hastings, Francis William, *m*
Hay, Robert John, *m*
Heberden, Henry
Henry, C. S. *l.c*
Henry, G. Cecil, *m*
Heyman, Henry
Hickes, H. J. F. E. *m*
Higgon, John D. George
Hill, Charles Rowland
Hill, Peter Edward
Hill, Frederick John George
Hodson, Robert
Holberton, T. N.
Holdsworth, John K.
Holmes George William
Hope, John Edward, *m*
Hope-Johnstone Charles J.
Hoste, D. E. C.B. *l.c*
Hughes, T. E.
Humfrey, Benjamin Geale
Hunter, C.
Hunter, Arthur S.
Hutchinson, A. H.
Ingilby, Charles Henry, *l.c*
Irvine, Hazlitt, *m*
Izod, William Henry
Jackson, Pilkington
Jervis, Henry Jervis W.
Johnson, Charles G.

Johnson, Alured C. *m*
Johnson, Augustus William
Johnston, Charles
Jones, Richard Paget C.
Jones, Richard Roynon
Joy, A. P.
Joyce, Leonard S.
Kaye, Arthur Lister
Kaye, N. L.
Keate, Edward
Kelly, John
Kerrick, W. D. S.
King, Augustus Henry
King, John Robert
Kinloch, D. J.
Knox, George Utcher
Lascelles, Claud G. W.
Law, Francis T. Adeane
Lawrence, W. H.
LeMesurier, Cecil B.,
LeMesurier, William G. C.B. *l.c*
Lempriere, H.
Lennox, A. Fred. F. *m*
Leslie, George
L'Estrange, P. W. *m*
L'Estrange, Champagne
Light, A. *m*
Lluellyn, William R.
Lovell, Charles Neville
Luard, Charles George
Lukin, William W. A. *m*
Lyle, Hugh Chetham
Lyon, Frederick L. H.
Lyon, Francis
Mackenzie, R. *m*
Mahon, Thomas
Mainwaring, Charles E.
Maitland, Eardley
Majendie, Vivian D.
Markham, Edwin, *adjt.*
Martin, Henry R.
Martin, William George
Marvin, W. *m*
Maude, Francis C. VC C.B. *l.c*
Maule, Henry B.
Maxwell, H. H. *l.c*
McGrigor, D. J.
McLaughlin, Edward
McTernan, C. L. H.
M'Dougall, Alexander J.
Mercer, Henry
Michell, John. E. *l.c*
Miller, Frederick, VC *m*
Milman, E. S.
Milman, G. H. L. *m*
Milman, George Alderson, *m*
Milward, Thomas W. *m*
Molony, Trevor Charles
Montague, W. *m*
Morris, William
Moubray, Edward, *m*
Murray, A. H.
Nangle, Walter C.
Newbolt, Robert H.
Newcome, William Henry
Newton, Horace Parker, *m*
Nicolls, Oliver H. A.
Nisbett, Francis Henry William
Noble, Andrew
Ogilvie, Alexander W. A.
O'Hara, Richard
Oldershaw, Charles Edw. *m*
Oldfield, Richard
Ommanney, F. M. M. *m*
Ord, Frederick William Craven
Orr, Andrew
Owen, Charles, H. *m*
Paget, Leopold Grimston
Palmer, Edmund, *m*
Papillon, A. F. W. *m*
Pasley, M. W. B. S.
Pearse, G. G. *m*
Pearse, Arthur T. G. *adjt.*
Pearson, J. R.
Peile, John Henry
Penn, Lewis W. *m*
Pennycuick, James F. *l.c*
Percival, Horace
Perssè, William N.
Phelips, Henry P. P. *adjt.*
Phillipps, P. Winsloe, *m*
Pigou, Arthur Comyn, *m*
Pipon, P. Gosset, *l.c*
Pitt, Henry D.
Pitt, Thomas Henry
Pollock, W. P.
Porter, Henry Richard
Price, John Andrew
Pulman, T.
Purcell, Edward Tobias W.
Purvis, H. M. Garret
Ravenhill, Frederick G.
Reilly, W. E. Moyses C.B. *m.*
Renny, G. A. VC *m*
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"ON THE CHANGE OF FORM ASSUMED BY WROUGHT-IRON AND OTHER METALS WHEN HEATED AND THEN COOLED BY PARTIAL IMMERSION IN WATER."*

BY LIEUT.-COL. H. CLERK, R.A., F.R.S.

Origin of the Experiments.

A short time ago, when about to shoe a wheel with a hoop-tire, to which it was necessary to give a bevel of about ⅜ths of an inch, one of the workmen employed suggested that the bevel could be given by heating the tire red-hot and then immersing it one-half its depth in cold water. This was tried, and found to answer perfectly, that portion of the tire which was out of the water being reduced in diameter. The tire was 3 inches wide, ½-inch thick, and 4′ 2″ in diameter.

As this result was curious and not generally known, I considered it desirable to institute some further experiments in order to try how far, by successive heatings and coolings, this change of form could be augmented, and also whether the same effect could be produced on other metals than wrought-iron.

Mode of carrying out the Experiments.

The experiments were made on cylinders of wrought-iron of different dimensions, both hollow and solid; immersed, some to one-half of their depth, others to two-thirds; also on similar cylinders of cast-iron, steel, zinc, tin, and gun-metal.

The specimens experimented on were all accurately turned in a lathe to the required dimensions, which were carefully noted; they were then heated to a red heat in a wood-furnace used for heating the tires of wheels. As soon as they had acquired the proper heat, they were taken out and immersed in water to one-half or two-thirds of their depth (as stated in the experiment). The temperature of the water ranged from 60° to 70° Fahr.

The specimens were allowed to remain in the water about two minutes, in which time the portion in the air had lost all redness, and that in the water had become sufficiently cool to handle. These alternate heatings and coolings were repeated till the metal showed signs of cracking or giving way.

The dimensions were noted after every five heatings. The circumferences were measured in preference to the diameters, as the true circular form was liable to alter.

* This paper is reprinted from the "Proceedings of the Royal Society;" and the Committee have to acknowledge the kindness of the President and Council in granting the use of the blocks for the wood cuts.

General Results.

It will be seen by an inspection of the figures that the general effect is a maximum contraction of the metal about one inch above the water-line; and that this is the same whether the metal be immersed one-half or two-thirds of its depth, or whether it be nine, six, or three inches deep. With wrought-iron the heatings and coolings could be repeated from fifteen to twenty times before the metal showed any signs of separation; but with cast-iron after the fifth heating the metal was cracked, and the hollow cylinder separated all round just below the water-line after the second heating. Cast-steel stood twenty heatings, but was very much cracked all over its surface. As respects the change of form of cast-iron and steel, the result was similar to that in wrought-iron, but not nearly so large in amount. The cast-iron did not return to its original dimensions, but the smallest diameter was about one inch above the water-line.

Tin showed no change of form, there being apparently no intermediate state between the melting-point and absolute solidity. Brass, gun-metal, and zinc showed the effect slightly; but instead of a contraction just above the water-line, there was an expansion or bulging.

The effect on wrought-iron is best seen in the solid cylinder (figs. 9 and 10), where the displacement of particles just above the water-line appears to be compensated by the bulgings at the two extremities.

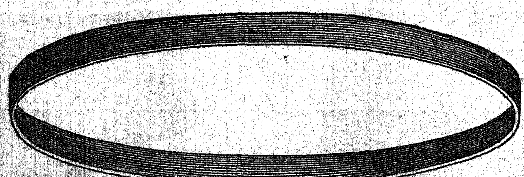
The specimens of wrought-iron were submitted by Mr Able (Chemist to the War Department) to chemical analysis, and he informs me that he found nothing noteworthy in the composition of the metal; nor was there any appreciable difference in the specific gravity of the metal taken from different parts of the specimen. It appears therefore to be simply a movement of the particles whilst the metal is in a soft or semifluid state.

The following is an account of the experiments, which were carried out under the superintendence of Mr Butter, draughtsman of the Royal Carriage Department, to whom also I am indebted for the accompanying diagrams. The exact dimensions of each specimen before and after heating are given in a tabulated form at the end of the paper, to facilitate comparison.

In figs. 22 and 23 the changes in form of the 9″ cylinders (one immersed one-half, the other two-thirds its depth) are shown in section after every five heatings (half the full size).

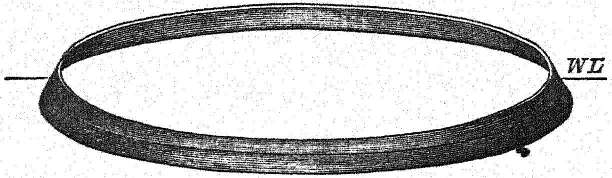
EXPERIMENT 1. A 4ft. 2 in. hoop-tire of 3 inches breadth and $\frac{3}{8}$ths inch in thickness (fig. 1) was heated and cooled by being immersed to half its depth in cold water five times, by which the effect shown in fig. 2 was produced.

Fig. 1.



One-eighteenth of full size.

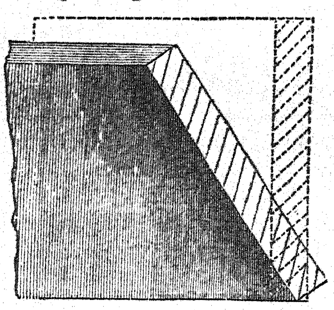
Fig. 2.



One-eighteenth of full size.

The upper edge, or that cooled in air, had contracted 8 inches, or $\frac{1}{20}$th its entire length, and slightly increased in thickness; while the lower edge, cooled in water, had expanded ·875 inch, making a difference between the two circumferences of 8·875 inches. The breadth remained unaltered (3 inches), and kept perfectly straight.

Fig. 3.



Section showing the amount of contraction. One-half the full size. The dotted lines show the original form.

The quality of the iron was afterwards tested by pieces taken from the upper and lower edges, and also from the centre; the fibrous condition had remained unchanged, the specific gravity had not altered appreciably, and there appeared to be no deterioration in any part of it.

EXPERIMENT 2. Two hollow cylinders of wrought-iron, 12 inches diameter and ½ inch thick each, and respectively 9 inches and 6 inches deep, were heated to redness, and cooled by half-immersion in cold water twenty times; for effects see figs. 4 and 5.

The 9-inch cylinder did not alter on the upper edge, cooled in air; but

Fig. 4.

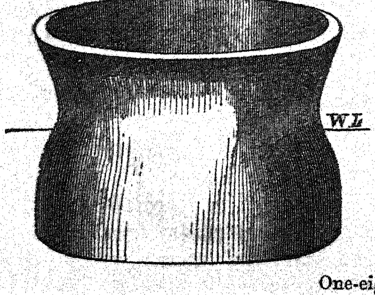
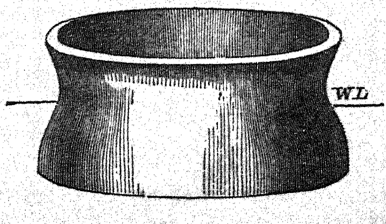


Fig. 5.



One-eighth of full size.

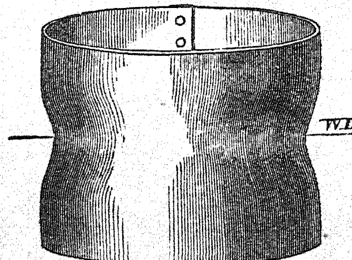
the lower edge, cooled in water, contracted ·6 inch, and the circumference, at about one inch above the water-line, was reduced 5·5 inches; the internal surface had increased in depth ·35 inch.

The small cylinder diminished ·7 inch on the upper edge, increased ·3 inch on the lower edge, and contracted 5·25 inches at about 1 inch above the water-line; the internal surface had increased in depth ·3 inch.

Experiment 3. A cylinder of very thin wrought-iron, so thin that it could not be welded, and was therefore riveted, of the same external dimensions as the 9-inch one of the foregoing experiment, was heated to redness and cooled by half-immersion ten times, in order to test the effect when the thickness of the metal was reduced as much as possible.

The upper and lower edges were not altered materially, while the greatest contraction took place on the water-line, instead of 1 inch above it as in the last experiment, and amounted to 3·5 inches. The depth measured on the curve had increased ·15 inch (see fig. 6).

Fig. 6.



One-eighth of full size.

Experiment 4. Two wrought-iron cylinders, exactly similar to those used in Experiment 2, were heated and cooled by being immersed to two-thirds their depth in water twenty times.

The upper edge of the large cylinder was reduced 2·1 inches, and the lower edge ·9 inch; it contracted 5·9 inches at about an inch above the water-line, and the inside surface had increased in depth ·35 inch (see fig. 7).

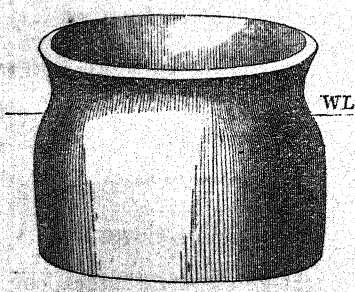


Fig. 7.

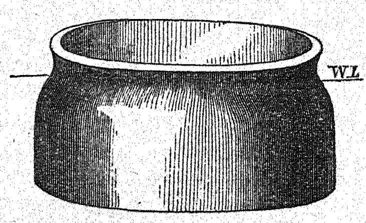


Fig. 8.

One-eighth of full size.

The upper edge of the small cylinder was reduced in circumference 3·6 inches and the lower edge ·65 inch, while the greatest contraction at about one inch above the water-line was 4·6 inches; and the internal surface had increased ·15 inch in height (see fig. 8).

Experiment 5. A solid cylinder of wrought-iron, 3 inches in diameter and 6 inches deep, was heated and cooled by being immersed half its depth in water fifteen times.

The greatest contraction took place a little above the water-line and on the lower edge, being in each case ·45 inch; the upper edge was reduced only ·1 inch.

Fig. 9.

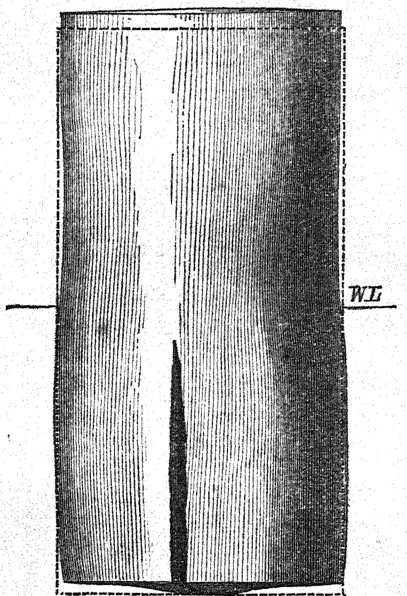
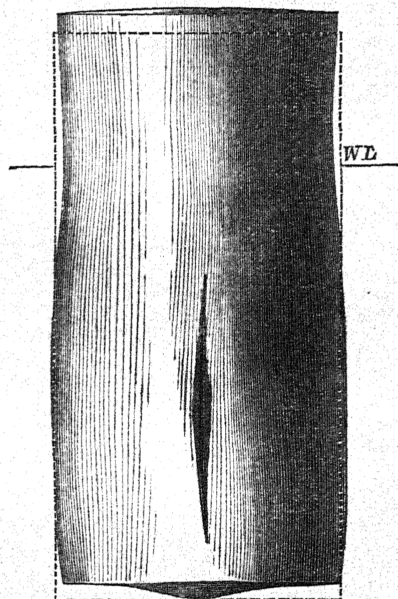


Fig. 10.



One-half of full size. The dotted lines indicate the original form.

A swell of metal took place on the two ends, but was greatest on the bottom, or that cooled in water, being ·15 inch in height.

The fibre of the iron opened at the fifteenth cooling (see fig. 9).

Experiment 6. A wrought-iron cylinder exactly similar to the last was cooled by being immersed to two-thirds its depth fifteen times.

The greatest contraction, amounting to ·4 inch, took place a little above the water line; the upper edge was ·05 inch smaller, and the lower edge ·35 inch, while the swellings on the ends were nearly the same as in the last experiment (see fig. 10).

The separation of the fibre took place at the fifteenth cooling.

Experiment 7. Two flat pieces of wrought-iron, each 12 inches long, 6 inches deep, and ·5 inch thick, were heated and cooled twenty times, one being immersed to half, and the other to two-thirds its depth in water.

That immersed one-half had contracted or become indented on the ends fully ·3 inch; the other had similar indentations, but to only one-half the amount. They were both turned up into the form of an arc, had thickened

on their upper edges, and increased ·1 inch in thickness where the contractions on the ends took place (see figs. 11 and 12.

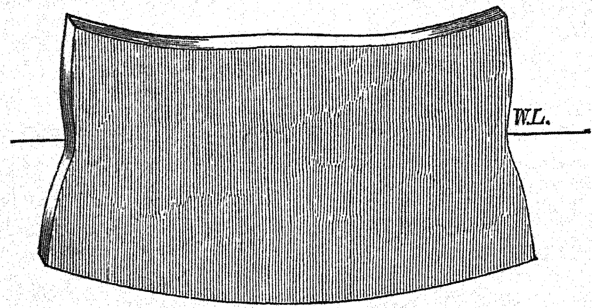


Fig. 11.

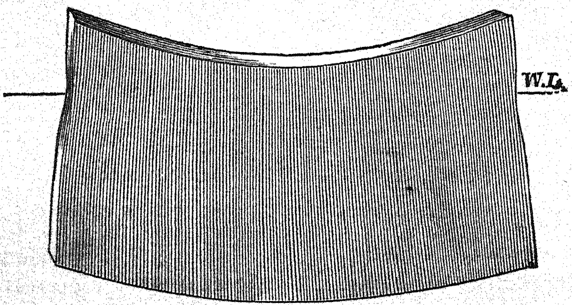


Fig. 12.

One-fourth of full size.

Experiment 8. Two hollow wrought-iron cylinders, 9 inches deep and 12 inches in diameter, were heated and cooled, one by simple exposure to air (fifteen times), and the other by total immersion in water (ten times). No alteration occurred in the form of either.*

Experiment 9. A solid cast-steel cylinder, of the same dimensions as that used in Experiment 5, was heated and cooled by half-immersion twenty times.

The effect obtained was similar to that produced upon the solid wrought-iron cylinders, but the breaking up of the structure was different (see fig. 13). The greatest contraction was slightly above the water-line, and amounted to ·38 inch; the bulgings on the ends were ·075 inch, being much less than on the wrought-iron cylinders.

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* The cylinder which was cooled in air weighed, before the experiment, 49 lbs. 14·5 oz. and after the experiment 49 lbs. 11 oz., showing a loss by scaling of 3·5 oz.

During the progress of the experiment, however, it was frequently weighed, and was found each time to have increased in weight up to the tenth heating, at which point it weighed 50 lbs. 1·125 oz., or 2·625 oz. heavier than it was at the commencement; from the tenth to the fifteenth heating the accumulated scales peeled off, and the weight was gradually reduced to that stated above.

That which was cooled in water weighed 50 lbs. 12·5 oz. before the experiment, and 48 lbs. 14·5 oz. at its conclusion, giving a loss of 1 lb. 14 oz., which was due to the action of the water peeling off the scale each time the cylinder was cooled.

Fig. 13.

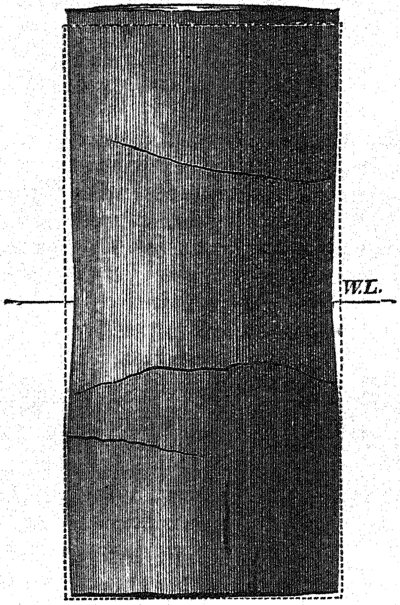


Fig. 14. (Top of fig. 13).

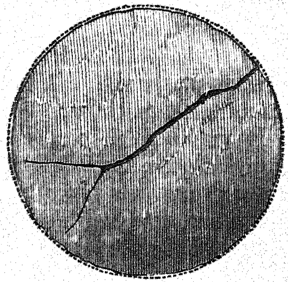
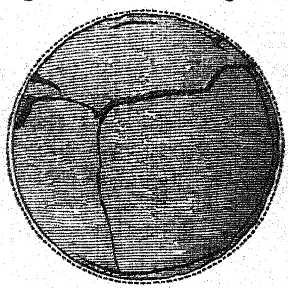
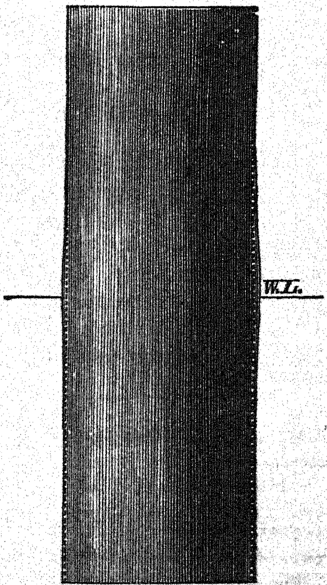


Fig. 15. (Bottom of fig. 13).



The four figures are one-half of full size. The dotted lines indicate the original figure.

Fig. 16.



EXPERIMENT 10. A hollow brass cylinder, 6 inches long, 2 inches in diameter, and $\frac{1}{16}$th of an inch thick, was heated to redness and cooled by half-immersion thirty-four times.

The effect produced was the opposite to that which took place with the iron cylinders, being an expansion instead of a contraction at the water-line, the amount of which was ·175 inch, and it was also expanded on the lower edge ·1 inch (see fig. 16).

EXPERIMENT 11. A hollow gun-metal cylinder was heated to redness and cooled twenty times by half-immersion.

The thickness of metal being greater than in the last experiment, the effect at the water-line was much less, but the lower edge had expanded ·1 inch. It began to crack all over at the last cooling.

EXPERIMENT 12. A hollow tin cylinder was heated in linseed-oil which was brought to a temperature of 400° Fahr.; it was cooled by half-immersion in water five times.

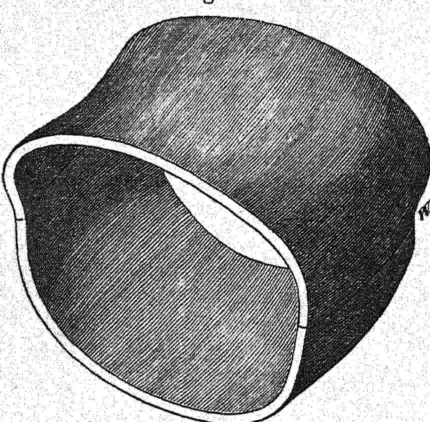
The form was not altered in the least, though the heat was raised in the last instance to the melting-point, as shown by the lower part of the cylinder beginning to melt.

EXPERIMENT 13. A hollow zinc cylinder was heated and cooled by half-immersion fifty times.

It was heated in a wood furnace, the degree of heat to which it was brought being regulated by the melting of a piece of tin which was conveyed at the same time with it into the furnace. Several experiments with pieces of tin and zinc had been previously made, by means of which it was ascertained that in the same temperature tin melted in two-sevenths of the time requisite to melt zinc; hence when the zinc cylinder and piece of tin were placed in the furnace together, the time occupied by the tin in reaching its melting-point was carefully noted, and the cylinder was left in the furnace as long again as the time thus observed; by this means it was brought very nearly to its melting-point without incurring any danger of its actually melting. The last five times, however, it was allowed to remain a little longer in the flame; and the melting upon the top was retarded the last four times by placing a piece of iron upon it, which conducted heat from that part, allowing it to remain half a minute longer in the furnace.

The effect obtained was the same as that produced upon the brass cylinder (Exp. 10), or the opposite of what took place with iron; an expansion of

Fig. 17.



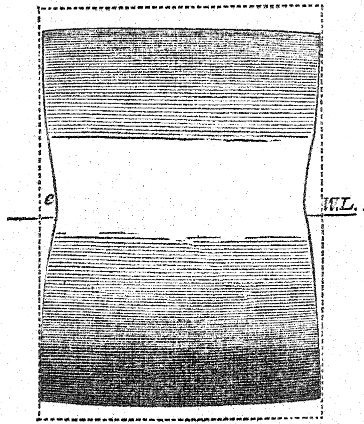
One-sixth of full size.

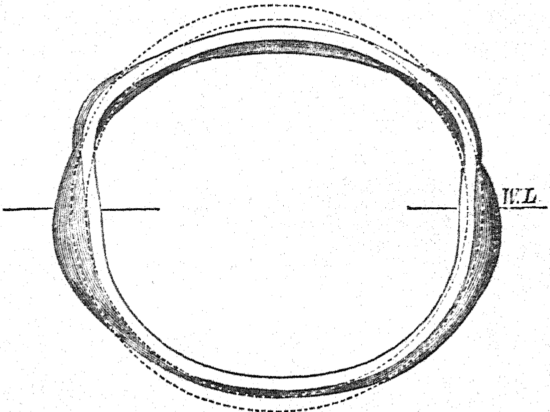
·175 inch occurred upon the water-line, and of ·115 inch upon the lower edge.

EXPERIMENT 14. The hollow wrought-iron cylinder was heated to redness and cooled by half-immersion on its *side*, instead of on its end as in other experiments, twenty times.

The effect was a very complicated one (see figs. 17, 18, and 19); the dotted lines show the original form.

Fig. 18. (Side view of fig. 17). Fig. 19. (Front view of fig. 17).





Figs. 18 and 19 are one-sixth of full size.

Experiment 15. A solid wrought-iron cylinder was heated to redness and cooled by half-immersion on its side twenty times.

The effect was of a similar nature to that of the last experiment (see figs. 20 and 21).

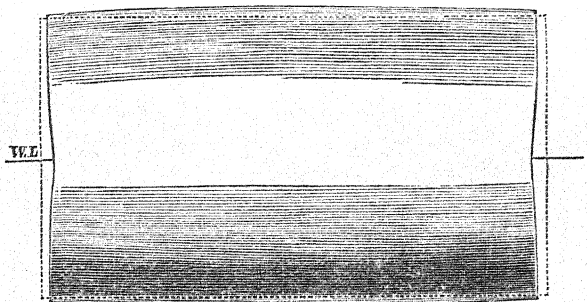
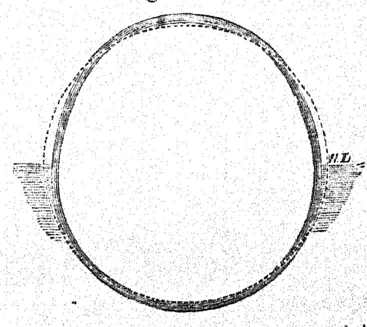


Fig. 20.

Figs. 20 and 21 are one-half of full size. The dotted line indicates original figure.

Fig. 21.



Experiment 16. A hollow cast-iron cylinder, the dimensions of which were the same as those of the deep cylinder of Experiment 14, was heated to redness and cooled twice by half-immersion.

At the second cooling it fractured nearly all round, about an inch below the water-line. It expanded all over, but the expansion was least about an inch above the water-line, i.e. it did not contract to its original dimensions.

EXPERIMENT 17. A solid cast-iron cylinder, 3 inches in diameter and 6 inches deep, was heated and cooled five times by half-immersion.

At the fifth cooling it cracked across the bottom; it also expanded throughout, and the expansion was least a little above the water-line, i.e. it did not contract to its original dimensions.

The subjoined figures (half the full size) show the changes produced on the 9-inch cylinders after every five heatings. (Experiments 2 and 4).

Fig. 22.

12″ cylinder, 9″ high, ½″ thick.
Vide fig. 4. Cooled by ½-immersion.

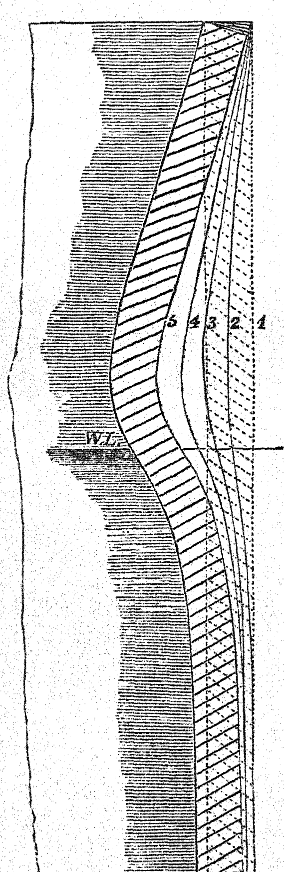
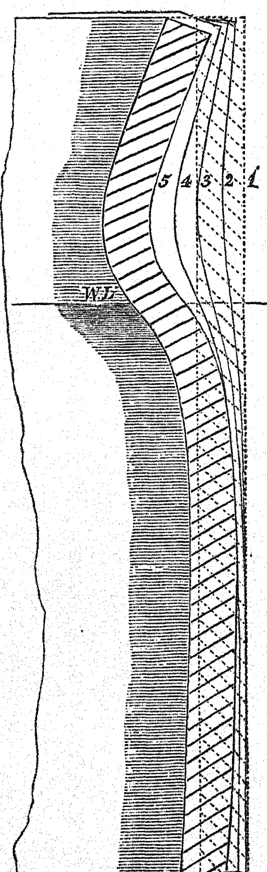


Fig. 23.

12″ cylinder, 9″ high, ½″ thick.
Vide fig. 7. Cooled by ⅔-immersion.



Nos. 1.	External	surfaces,	original forms.		
2.	”	”	after 5	coolings.	
3.	”	”	”	10	”
4.	”	”	”	15	”
5.	”	”	”	20	”

TABULATED STATEMENT OF THE RESULTS OF THE EXPERIMENTS.

Number of experiment.	Kind of metal.	Number of coolings.	Amount of immersion.	Form of article, &c.	Dimensions, in inches. Before experiment.	After experiment.	Difference.
1[a]	Wrought-iron.	5	½	Hoop-tire for a 4′ 2″ wheel:—			
				External circumf. of upper edge......	155·5	147·5	—8·0
				do do lower edge......	155·5	156·375	+0·875
				Bevel of face	90°	69°	—21°
2[b]	Wrought-iron.	20	½	12″ cylinder, 9″ deep and ½″ thick:—			
				Internal circumf. of upper edge	37·6	37·6	0·0
				do do contraction......	37·6	32·1	—5·5
				do do lower edge	37·6	37·0	—0·6
				Depth, perpendicular	9·0	8·8	—0·2
				do on curve, external	9·0	9·15	+0·15
				do do internal	9·0	9·35	+0·35
2[c]	Wrought-iron.	20	½	12″ cylinder, 6″ deep and ½″ thick:—			
				Internal circumf. of upper edge	37·6	36·9	—0·70
				do do contraction......	37·6	32·35	—5·25
				do do lower edge	37·6	37·9	+0·30
				Depth, perpendicular	6·0	5·7	—0·30
				do on curve, external..............	6·0	6·05	+0·05
				do do internal..............	6·0	6·30	+0·30
3[d]	Wrought-iron.	10	½	12″ cylinder, 9″ deep, thin sheet:—			
				External circumf. of upper edge......	38·40	38·40	0·00
				do do contraction......	38·40	34·90	—3·50
				do do lower edge......	38·40	38·45	+0·05
				Depth, on curve..........................	9·00	9·15	+0·15
4[e]	Wrought-iron.	20	⅔	12″ cylinder, 9″ deep and ½″ thick:—			
				External circumf. of upper edge......	40·90	38·80	—2·10
				do do contraction......	40·90	35·00	—5·90
				do do lower edge......	40·90	40·00	—0·90
				Depth, perpendicular	9·00	8·80	—0·20
				do on curve, external..............	9·00	9·00	0·00
				do do internal..............	9·00	9·35	+0·35
4[f]	Wrought-iron.	20	⅔	12″ cylinder, 6″ deep and ½″ thick:—			
				External circumf. of upper edge......	40·8	37·2	—3·6
				do do contraction......	40·8	36·2	—4·6
				do do lower edge......	40·8	40·15	—0·65
				Depth, perpendicular....................	6·0	6·0	0·0
				do on curve, external..............	6·0	6·05	+0·05
				do do internal..............	6·0	6·15	+0·15
5[g]	Wrought-iron.	15	½	3″ cylinder, 6″ deep, solid:—			
				Circumference, upper edge	9·4	9·3	—0·1
				do contraction	9·4	8·95	—0·45
				do lower edge	9·4	8·95	—0·45
				Bulge on upper end	0·00	0·04	+0·04
				do lower end	0·00	0·15	+0·15
6[h]	Wrought-iron.	15	⅔	3″ cylinder, 6 deep, solid:—			
				Circumference, upper end	9·40	9·35	—0·05
				do contraction	9·40	9·00	—0·40
				do lower edge	9·40	9·05	—0·35
				Bulge on upper end	0·00	0·05	+0·05
				do lower end	0·00	0·20	+0·20

[a] The width was unaltered, and the thickness of the upper edge slightly increased. Figs. 1 and 2.
[b] Fig. 4. [c] Fig. 5. [d] Fig. 6. [e] Fig. 7. [f] Fig. 8.
[g] The fibre opened at the fifteenth cooling. Fig. 9.
[h] The fibre opened at the fifteenth cooling after having exhibited a slight crack for two or three previous coolings. Fig. 10.

TABLE.—*Continued.*

Number of experiment.	Kind of metal.	Number of coolings.	Amount of immersion.	Form of article, &c.	Dimensions, in inches. Before experiment.	After experiment.	Difference.
7[i]	Wrought-iron.	20	½	Flat piece, 12″ × 6″ × ½″:—			
				Length on curve, upper edge	12·00	10·75	−1·25
				do do lower edge	12·00	12·10	+0·10
				Breadth, ends	6·00	5·75	−0·25
				do centre	6·00	6·00	0·00
				Upper edge, out of straight...........	0·00	0·60	+0·60
				Indentation on ends	0 00	0·30	+0·30
7[k]	Wrought-iron.	20	⅔	Flat piece, 12″ × 6″ × ½″:—			
				Length on curve, upper edge	12·00	11·10	−0·90
				do do lower edge	12·00	12·20	+0·20
				Breadth, ends..............................	6·00	5·87	−0·13
				do centre	6·00	5·95	−0·05
				Upper edge, out of straight...........	0·00	0·50	+0·50
				Indentation on ends	0·00	0·15	+0·15
8[l]	Wrought-iron.	15 10	0 total	12″ cylinder, 9″ deep, ½″ thick do do do	No	effect.	
9[m]	Cast-steel.	20	½	3″ cylinder, 6″ deep, solid:—			
				Circumference, upper edge	9·03	8·93	−0·10
				do contraction	9·03	8·65	−0·38
				do lower edge	9·03	8·93	−0·10
				Depth, perpendicular	6·00	6·10	+0·10
10[n]	Brass.	34	½	2″ cylinder, 6″ deep, 1/16″ thick:—			
				External circumf. of upper edge ...	6·175	6·175	0·000
				do do expansion	6·175	6·350	+0·175
				do do lower edge	6·175	6·270	+0·095
11[o]	Gun-metal.	20	½	3″ cylinder, 6″ deep, ½″ thick:—			
				External circumf. of upper edge ...	9·25	9·24	−0·01
				do do on water-line......	9·25	9·26	+0·01
				do do of lower edge......	9·25	9·38	+0·13
12	Tin.	5	½	2″ cylinder, 5″ deep, ¼″ thick...........	No	effect.	
13	Zinc.	50	½	3″ cylinder, 6″ deep, ½″ thick:—			
				External circumf. of upper edge ...	9·525	9·575	+0·050
				do do expansion	9·525	9·700	+0·175
				do do lower edge......	9·525	9·630	+0·105
14[p]	Wrought-iron.	20	½ on its side.	12″ cylinder, 9″ deep, ½″ thick:—			
				External circumference of edges ...	40·65	39·86	−0·79
				do do centre ...	40·65	41·05	+0·40
				Depth on curve, part cooled in air...	9·00	9·00	0·00
				do do water-line......	9·00	8·25	−0·75
				do do in water	9·00	8·80	−0·20
				Swell of side, 1″ below W. L. (at *a*, *b*)	0·00	1·00	+1·00
				Hollow of side, 4″ above do (at *c*, *d*)	0·00	0·40	+0·40
				Longest ex. diam. 1″ below W. L....	12·94	14·275	+1·335
				Shortest do at rt. angles to W. L. ...	12·94	12·00	−0·94
				Indentation of edges a little above water-line at *e*	0·00	0·45	+0·45

[i] The thickness of the metal at the indentation on ends increased ·1″. Fig. 11.
[k] The thickness of the metal at the indentation on ends increased similarly to the last. Fig. 12.
[l] Cooled in air 15 times. Cooled in water 10 times.
[m] The ends became slightly rounded. Fig. 13.
[n] At the last cooling the lower end of the cylinder began to crumble away in the water. Fig. 16.
[o] The expansion of the lower end may probably be due to the cracking of the metal, which was greatest at that part.
[p] Figs. 17, 18, 19. There was an increased thickness of metal at *e*.

TABLE.—*Continued.*

Number of experiment.	Kind of metal.	Number of coolings.	Amount of immersion.	Form or article, &c.	Dimensions, in inches. Before experiment.	After experiment.	Difference.
15[q]	Wrought-iron.	20	½ on its side.	3″ cylinder, 5¾″ deep, solid:—			
				External circumference of edges ...	9·4	9·2	—0·2
				do do centre...	9·4	9·475	+0·075
				Depth along part cooled in air.........	5·375	5·150	—0·225
				do do on W. L. ...	5·375	5·100	—0·275
				do do in water......	5·375	5·225	—0·150
				Longest diam. at rt. angles to W. L.	3·000	3·100	+0·100
				Shortest do. parallel with W.L. and a little below it	3·000	2·760	—0·240
16	Cast-iron.	2	½	12″ cylinder, 9″ deep, ½″ thick :—			
				External circumf. of upper edge ...	40·90	41·05	+0·15
				do do least expansion	40·90	40·95	+0·05
				do do lower edge......	40·90	41·15	+0·25
17	Cast-iron.	5	½	3″ solid cylinder, 6″ deep:—			
				External circumf. of upper edge ...	9·4	9·55	+0·15
				do do least expansion	9·4	9·50	+0·10
				do do lower edge......	9·4	9·55	+0·15

[q] Figs. 20, 21.

ACCOUNT

OF AN

EXPERIMENT CARRIED ON AT SHOEBURYNESS, 27TH APRIL, 1863, AGAINST A TARGET PROPOSED BY MR CHALMERS, AND CONSTRUCTED AT THE MILLWALL IRONWORKS.

[CONTRIBUTED BY CAPTAIN E. J. BRUCE, R.A.]

The target (13′ 4″ long by 10′ high) was composed of $3\frac{3}{4}$-in. armour plates, backed by alternate layers of timber and iron $10\frac{3}{4}''$ thick, placed horizontally and bolted together; then a second armour plate $1\frac{1}{4}$-in. thick, with a cushion of timber $3\frac{3}{4}$-in. thick between it and the $\frac{5}{8}$-in. plate forming the skin of the ship; the iron plates used in the backing, between the 1st and 2nd armour plates, were $\frac{3}{8}$-in. in thickness and 5-in. apart from centre to centre. The armour plates were secured to the skin by through bolts, $2\frac{1}{4}$-in. diameter, having stepped conical necks, and a square thread, with double nuts and elastic washers. An iron plate, $\frac{3}{4}$-in. thick, was riveted on each end of the target, and a $\frac{5}{8}$-in. plate on the top.

The target was supported against one of the Hawkshaw targets.

Weight per superficial foot of Mr Chalmers' target	....	371 lbs.
do "Warrior" do	....	341 lbs.

The following guns were used in the experiment:—

One 300-pr. Armstrong muzzle-loading shunt gun.
Three 110-pr. Armstrong breech-loading rifled guns.
Two 68-pr. smooth-bore guns.

The following shot and shell struck the target:—

From 300-pr. gun—

		Total weight in lbs.
Steel solid shot,	1	301
Spherical, cast-iron,	2	299

From 110-pr. guns—

Solid shot, cast-iron,	6........................	662
do do	6 (197 lbs. each)	1182
Shell do	6........................	624

From 68-pr. guns—

Solid shot, cast-iron,	3........................	198
Shell do	4........................	198

Total 3464 lbs. weight of shot struck the target.

Number of round.	Photographic No.	Nature of ordnance.	Projectile. Nature.	Projectile. Weight in lbs.	Charge in lbs.	Elevation.	Range in yds.	Deflection.	Effects. Depth of indent in inches.	Effects. Diameter of indent in inches.	Effects. Bulge of plate in inches.	Remarks.
						′		′				
1	564	110-pr	Shell filled with sand.	104	12	24	200	14 R	·4	...	...	Struck centre plate 1′ 6″ from bottom, and 4′ 4″ from left side.
2	565	„	„	„	„	...	„	„	·5	...	...	Struck centre plate 6″ from the top, and 5′ 1″ from the right side; the plate driven in 1·5″ in a length of 3′.
3	566	„	„	„	„	...	„	„	·4	...	...	Struck the lower plate 6″ from the top, and 7′ 3·5″ from the right side. A bolt 1′ 2″ from indent started ·4″; and a crack, 19″ long, extended through a bolt-hole at 1′ 4·5″ from impact. At the back, after these three rounds, five rivet-heads were off.
4	567	68-pr.	„	49½	16	...	20′	nil	1·55	9·	...	Struck the centre plate 1′ 4·5″ from the top, and 5′ 1·75″ from the right side. At the back, two rivet-heads off.
5	568	„	„	„	„	...	„	„	1·25	9·	...	Struck the lower plate 7·5″ from the top, and 6′ 8·5″ from the right side; a crack 8″ long parallel to the circumference of indent, and 9″ below it; a crack 6″ long from the top of the plate, at 9″ from indent; three small cracks below indent, and parallel to its circumference; also a narrow crack, 9″ long, from a bolt-hole, 1′ from impact. This round struck near No. 3, and the plate is now driven in 1·25″. One rivet-head off at the back of the target, and several india-rubber washers compressed.
6	569	110-pr	Shell filled with powder.	104	12	...	24′	14 R	·7	...	...	Hit at the junction of the centre and upper plates, 4′ from the right side. The centre plate started ·25″ at right side.
7	570	„	„	„	„	...	„	„	„	...	...	Hit the upper plate, 1′ 3″ from bottom, and 6′ 6″ from the right side.
8	571	„	„	„	„	...	„	„	„	...	...	Hit the upper plate 1′ 6″ from bottom, and 4′ 5″ from left side. At the back of the target, after rounds 6, 7, 8, one rivet-head was off, and a slight curvature of one side of a double rib.
9	572	68-pr.	„	49½	16	...	20′	nil	1·5	9·5	...	Struck the lower plate 6″ from the bottom, and 4′ 3″ from the right side.
10	573	„	„	„	„	...	„	„	„	10·	...	Struck the lower plate 1′ 3·5″ from the bottom, and 4′ 5″ from the left side. The crack from bolt-hole made by round No. 5 much widened, and now extends to the bottom of the plate; three small cracks on the indent of round No. 5.
11	574	110-pr	Solid cast-iron shot.	110¼	14	...	24′	14 R	1·5	7·	3·	Struck the top plate 1′ 2″ from the left side, and 1′ 6″ from the bottom. A wide crack on face of indent; the plate was forced up ·5″ from the centre one, and started 1·6″ at bottom and 1·3″ at top on left side, and had started from the backing for a length of 3′ from the left side. Three rivets broken in the ¾-in. plate on left side of target.
12	575	„	„	„	„	...	„	„	1·2	6·75	2·7	Struck the centre plate 1′ 4″ from the top, and 2′ 2·5″ from the left side. The plate cracked slightly in indent, and a narrow crack 2″ long, 6″ above indent. The plate started 1·4″ at top, and 1·3″ at bottom on left side.

Number of round.	Photographic No.	Nature of ordnance.	Projectile. Nature.	Projectile. Weight in lbs.	Charge in lbs.	Elevation. ′	Range in yds.	Deflection. ′	Effects. Depth of indent in inches.	Effects. Diameter of indent in inches.	Effects. Bulge of plate in inches.	Remarks.
13	576	110-pr	Solid cast-iron shot.	$110\frac{1}{4}$	14	24	24′	...	1·8	7·7	3·45	Struck the lower plate 1′ 4·5″ from the left side, and 1′ 3·5″ from bottom. A crack, 7·5″ long, 8″ to left of indent; lower left-hand bolt started ·5″; the plate started 2″ at bottom, and 1·3″ at top on the left side. Seven rivet-heads were broken off by the last three rounds.
14	577	68-pr.	„	$66\frac{1}{4}$	16	...	20′	nil	2·5	8·5	3·5	Struck the centre plate 8″ below round No. 4 (from centre to centre). The indents of the two rounds measure 16″ in length; a crack, 3·5″ long on indent, and five cracks on indent of round No. 4; plate started ·1″ on right side. No damage to the rear of target.
15	578	110-pr	„	197	10	...	45′	14 R	·8	...	...	Struck top plate 9″ from bottom, and 5′ 5″ from left side.
16	579	„	„	„	„	...	„	„	1·0	...	...	Hit centre plate 9″ from bottom, and 5′ 11″ from left side.
17	580	„	„	„	„	...	„	„	...	...	...	Hit lower plate 6″ from round No. 10; indent very slight. At the back, three inner armour-plate bolts broken.
18	581	„	„	„	„	...	„	„	·4	...	...	Fired in salvo, and struck the centre plate in a space measuring 1′ 3″ square. Round 18 struck at 1′ 2″ from bottom of plate; round 19 at 1′; and round 20 at edge of the plate. At the back, three rivet-heads off, and two ribs slightly buckled.
19	582	„	„	„	„	...	„	„	·7	...	...	
20	583	„	„	„	„	...	„	„	1·5	...	2·5	
21	584	68-pr	„	$66\frac{1}{4}$	16	...	20′	„	...	...	...	Struck three yds. short, and passed under target, only grazing the bottom of the lower plate.
22	585	110-pr	...	...	...	...	„	„	...	...	...	Fired in salvo, and struck on the right end of the upper plate. Two 68-pr. shot and one 110-pr. struck in a space measuring 2′ 7″ × 1′ the 110-pr. at the junction of the centre and upper plates, and the two 68-prs. on a bolt, the two indents of the latter measuring 14″ in length; the upper plate driven in 4″ at bottom below 68-pr. indents, wide cracks on each side of 68-pr. indents. Indents of 110-pr. 2·5″, 2·″ respectively; cone remained in one indent; wide crack across right 68-pr. indent, extending to a bolt-hole; crack, 5″ long, from top of centre plate below 68-pr. indents. Upper plate forced up ·75″. At the back, one through bolt broken and driven out (fracture not in thread of screw, but in shank); one rib buckled. Two small bolts (bolting the wood backing to the skin) started ·2″ and ·5″.
23	586	„										
24	587	„										
25	588	68-pr.										
26	589	„										
27	590	300-pr	Steel solid shot.	301	45	..	20′	4 R	through.	...	...	Struck at the junction of the centre and upper plates, at 4′ 4″ from the left edge of target, and on a bolt, penetrated the target, and made a hole $14\frac{1}{2} \times 13''$. At the back, fragments of plate, backing, &c., driven through; large irregular hole, 2′ × 1′ 6″; general bulge of skin over 4′ 6″ × 3′ 6″; one rib smashed and driven back 1′ 6″; ragged inner skin sticking out 1′; many adjoining rivet-heads off. The shot "set-up" 1·93″.

Number of round.	Photographic No.	Nature of ordnance.	Projectile. Nature.	Projectile. Weight.	Projectile. Form.	Charge in lbs.	Elevation.	Range in yds.	Deflection.	Effects. Depth of indent in inches.	Effects. Diameter of indent in inches.	Effects. Bulge of plate in inches.	Remarks.
28	591	300-pr	Cast-iron solid shot.	lbs. oz. 149 10	Spherical. " 10·369 diamr.	50	′ 18	200	′ nil.	...	...	...	Struck at the junction of the upper and centre plates, at 3′ 6″ from right side of the target; penetrated to a depth of 11″, and made a hole in the front of the target measuring 14″ × 11″; two through bolts broken, one at 15″ from point of impact; five inner armour-plate bolts broken, and one driven in 3″; five rivets broken; a rib bulged out 2″ in a length of 4′, and another rib bent ½″ in 3′; considerable bulge of skin over a space of 3′ × 2′, and the skin opened ½″ at the junction of the plates; one angle-iron of rib broken. When the front armour plate was removed, the backing was found to have been affected for about 3′ 6″ on each side of the hole, being 2″ out of the plane at the greatest depth.
29	592	"	"	"	"	"	5	"	7½	...	...	...	Struck the lower plate 10″ from the right side and 8″ from the top, touching a bolt; made a hole in target 12″ diameter, penetrated to a depth of 12″, and shot broke up in hole; the upper right-hand corner of the plate, the sides measuring 11″ × 9″, was detached and was forced 4″ into the backing at the side next the hole; two inner armour-plate bolts and three rivets were broken; the skin was slightly bulged over a space of 2′ × 1′ 6″, and was cracked for a length of 12″, the crack being ·6″ wide in the widest part; one angle-iron of rib broken, and the india-rubber washers of the through bolts much compressed.

ON

A CURIOUS INSTANCE OF ELECTROLYTIC ACTION.

BY F. A. ABEL, F.R.S.

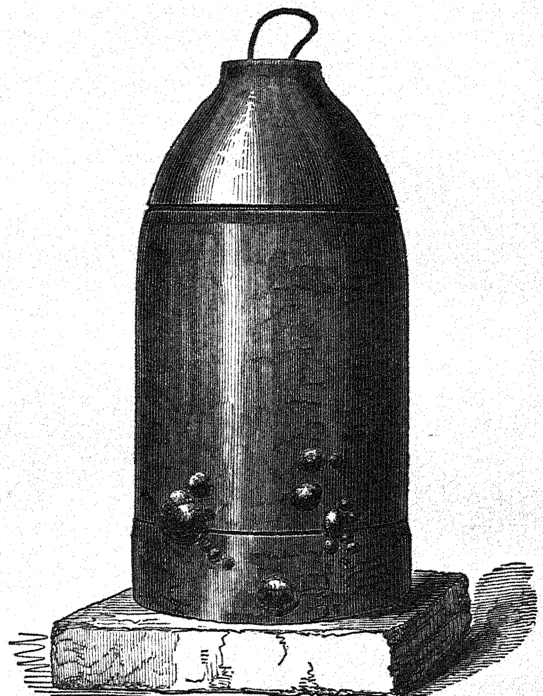
[COMMUNICATED BY THE SECRETARY, R.A.I.]

The inspection of a number of the lead-coated projectiles, employed with the Armstrong guns, has recently brought to light some curious and quite unexpected instances of the establishment of voltaic action within the coatings of certain of these projectiles, and in positions where the existence of an exciting cause was not at all anticipated.

It has been customary to attach the coating of soft-metal (which is an alloy of lead with a small proportion of tin or antimony) to the body of the cast-iron projectiles, by two different methods. The one consists in providing the iron surfaces with a number of grooves formed at somewhat acute angles with the surface; the soft metal with which these become filled when it is cast over the shot or shell, serves to attach the coating firmly to the body. The other method consists in first alloying and coating the surface of iron with zinc (by the so-called galvanizing process), and then immediately covering it with the soft metal. The covering of zinc fixed, in this instance, upon the iron, becomes the medium by which the coating of lead-alloy is attached to the body of the projectile. By the latter method, therefore, a perfect juncture is accomplished between the two parts, while, by that first-named, they may be said to be fitted together accurately, or riveted together.

The different manner in which the iron and the lead-alloy are affected by considerable changes of temperature has led, in a few instances, of a very special character, to a distortion of the coatings which have been attached by the mechanical method (i.e. by means of grooves) in consequence of their partial separation from the body of the projectiles. The alterations in form presented by some shells of this class, which have been exposed for a time to the effects of considerable changes of temperature, differ, however, altogether from those exhibited by a small proportion, among a number inspected, of shells, the lead-coatings of which were attached by means of zinc. On various parts of these shells, the soft metal was found to have become raised in the form of blisters, varying in size from ¼ inch to 1 inch in diameter. A large (110-pr.) shell, which had been preserved officially, as a standard pattern, since November, 1861 (having been kept in a glass case), exhibited, upon its coated surface, in addition to numerous smaller blisters, one measuring 1·1 inch in diameter, and projecting ¼ inch beyond the surface of the shell (see fig). These projections, or blisters, were not confined to any particular position upon the different shells; neither had those projectiles, which exhibited them, been exposed to any considerable changes of temperature.

The only inference deducible from the appearance of these projectiles was, that the blisters had been produced in consequence of the generation of gas at those parts of the shells between the iron surface and the coating of soft metal, which gas had gradually accumulated to such an extent as to be placed under very considerable pressure, and, consequently, to exert, eventually, an amount of force sufficiently great to tear



comparatively plastic alloy of lead. This influence was fully borne out by the following results of examination of the blisters.

When these were punctured, under water, a quantity of gas, existing evidently under considerable pressure, made its escape. The gas was separately collected from blisters upon different shells, and was found, in all instances, to consist of pure hydrogen.

The entire volume of gas, enclosed in the large blister specially referred to above, was carefully collected, and its volume was determined. The capacity of the blister was afterwards measured, and the results furnished by these determinations showed that the hydrogen existed at the period of examination, under a pressure very slightly exceeding ten atmospheres.

By carefully cutting through the metal surrounding the blisters, several, which had been otherwise operated upon, were removed from the shells, the internal surfaces remaining untouched. On a close inspection of these surfaces, they were all found to resemble each other closely, those of the blisters as well as those of the iron body of the shell, immediately beneath them. They presented a frosted metallic appearance, small dark patches or spots, indicative of corrosion, being visible here and there. Those of the blisters and of the iron beneath were alike coated with zinc, and their peculiar appearance, just referred to, was to be ascribed to the existence, upon them, of numerous small projections, such as are observed upon the surfaces laid bare when a piece of metal is fractured by a tensile strain.

It is evident, from the foregoing details, that the projections, or blisters, which have been described, had been produced by the gradual disengagement of hydrogen between the body of the projectile and the coating of lead-alloy, whereby the two descriptions of metal, joined together thoroughly in the first instance (except probably at a few minute points) through the medium of zinc, had been torn asunder, and the thin intermediate zinc coating itself divided, the gas gradually creating further space for itself by expanding the envelope of soft metal which confined it.

That these results must have been due to the electrolytic decomposition of some hydrogen-compound, which had become enclosed between the metals, is self-evident; an examination into the process of manufactures of these projectiles, aided by a few simple experimental data, appears to leave no doubt regarding the primary cause of this disengagement of gas.

the aid of the so-called galvanizing process, are as follow:—The cast-iron projectile, after having been turned, so as to present a perfectly clean metallic surface, is heated in an oven until its temperature approaches the fusing point of zinc; it is then plunged into a solution of sal-ammoniac, almost immediately withdrawn, and immersed in a bath of melted zinc, where it remains for about two minutes, when it is transferred to a bath of the lead-alloy with which it is to be coated. After remaining in this bath also for a period of two minutes, it is withdrawn and placed in a mould. The projectile thus treated has become uniformly covered with a thin coating of soft metal, the thickness of which is afterwards increased, by pouring a further quantity of the alloy round the coated projectile, directly it has been placed in the mould.

When the heated projectile is passed from the chloride of ammonium solution to the bath of zinc, portions of the salt remain adhering to the iron, upon its immersion in the zinc, and there is no doubt that a small proportion of water may also, occasionally, be carried along with it, so as to be brought together with it into contact with the melted metal. A small proportion of chloride of zinc is always formed at this stage of the process, by decomposition of the chloride of ammonium, in consequence of the high temperature at which particles of this salt are brought into contact with the zinc, and with oxide of zinc, small portions of which may accidently attach themselves, at the moment of immersion, to any slight inequalities on the surface of the iron. The remarkable tendency of chloride of zinc to absorb and retain water, even at very high temperatures (the latter being only gradually expelled from it, even at the temperature of melted zinc), renders it easily conceivable that, at the time of production of the zinc-salt, any water accidentally present, besides that which results from the decomposition of the ammonium-salt by oxide of zinc, will at once be absorbed by it; there is no doubt, therefore, that any particles of chloride of zinc accidentally enclosed by the zinc-coating formed upon the iron surface, will still retain some water at the expiration of the brief period during which they continue exposed to the high temperature of the zinc-bath. Afterwards, when the coating of zinc becomes, in its turn, speedily enveloped in that of the lead-alloy, the temperature of the projectile gradually diminishing up to the termination of the process, the escape, or decomposition, of the water, through the agency of heat, is speedily arrested.

Thus it is that portions of water become accidentally enclosed between the iron body and the zinc-coating of compound projectiles prepared by this system; and it is this enclosed water which afterwards suffers gradual decomposition through electrolytic agency; the accumulation of the liberated hydrogen giving rise, eventually, to the projections or blisters in the coating of soft metal.

The surfaces laid bare by carefully cutting open many of these blisters, invariably furnished proof that chloride of zinc had been enclosed at those places, and that a basic chloride had been formed. Water removed from them a mere trace of chlorine, but, by a brief treatment with dilute acetic acid, abundant evidence was obtained of the existence of a chloride within the blisters.

It should be observed that these accidental distortions of the lead-coating on Armstrong projectiles which have been prepared by means of the galvanizing process, appear not to be of frequent occurrence, and that they do not interfere with the efficiency of such projectiles, because, even in the most striking instances, they constitute only a very small proportion of the coating of soft metal, which is, in all other parts, inseparably joined to the iron; and also, because the coating may, in places where it has been raised in

REPORT

OF

ORDNANCE SELECT COMMITTEE.

No. 2685, dated 6th February, 1863.

ON COMPETITIVE RIFLED CAST-IRON GUNS.

Brigadier-General ST GEORGE, C.B., R.A.
Captain Sir W. WISEMAN, Bart., R.N.
Brevet-Colonel HOGGE, C.B., R.A.
Brevet-Colonel F. A. CAMPBELL, R.A.
Lieut.-Colonel R. S. BAYNES, Unattached.
Lieut.-Colonel GALLWEY, R.E.
Brevet-Colonel LEFROY, R.A., *Secretary*.

[Communicated by direction of the Secretary of State for War].

THE Ordnance Select Committee have the honour to report to Secretary Sir G. Cornewall Lewis the results of an extensive trial of cast-iron 32-pr. guns, rifled for different gentlemen, in accordance with their respective views of the best way of rifling the existing store of smooth-bored cast-iron guns, under instructions first communicated to the Committee by Lord Herbert, in August, 1859 (Appendix I. p. 342).

The following were the competitors :—

Mr Bashley Britten.	Mr A. Jeffery (added in Dec. 1859).
Mr Lynall Thomas.	Mr J. Nasmyth.
Mr J. C. Haddan.	Mr J. Whitworth.
Mr C. W. Lancaster.	Commander R. A. E. Scott, R.N.

Mr Whitworth did not deliver his gun in a rifled state until August, 1862, and has therefore taken no part in the competition, which was closed as regards competitive practice in 1861. The Committee, however, having had occasion in the course of the inquiry to express their opinion on the merits of polygonal rifling, this Report, No. 1708, is subjoined (Appendix IV. p. 349).

Commander Scott was not among the gentlemen originally invited to rifle a gun for trial; but having obtained permission, in November, 1859, to have a service 32-pr. rifled at his own expense, in the Royal Gun Factories, and subsequently a second gun, which has been tried concurrently with the others, he is here, for convenience, included in the list.

Mr Nasmyth received permission, in August, 1859, to convert his gun into a breech-loader, before rifling it, and in that state it was ultimately ordered to be tested to destruction. The gun burst on 21st September, 1859 (Appendix II. p. 345), at the 27th round, being the 7th round with cylinders of 96 lbs., charge 10 lbs. The Committee reported (No. 275, July 10, 1859) their opinion that the system of breech-loading adopted was one which weakened the breech of the piece too much to allow of its application to the existing service guns, and no further steps have been taken to realize Mr Nasmyth's propositions. A 32-pr. gun, rifled by direction of the Secretary of State for War, on the system of the *canon de* 30 *rayée* of the French navy, has also been included; and lastly, a 32-pr., prepared by Sir William Armstrong, for some preliminary experiments on the shunt mode of rifling, but without any intention on his part of proposing it for rifling smooth-bored cast-iron guns.

2. The whole of the guns selected were new 32-prs., of 58 cwt., of Messrs Hood's manufacture, cast and smooth-bored at Lowmoor.

The metal of this foundry is distinguished by high specific gravity, and great tensile strength. The mean of 42 samples (enumerated Appendix III. p. 348), gives a tensile strength of 28,501 lbs. to the square inch, or 12·71 tons. Tested by weight, suspended from a bar 2 inches square, and 10 inches between the bearings, 11 samples gave a transverse resistance of 27,969 lbs.; 7 samples cut 2 inches square, and 20 inches between the bearings, broke with a mean pressure of 9254 lbs. Comparing these results with the abstract of corresponding tests applied to 51 different makes of iron given in the Report of Colonel F. Eardley-Wilmot, in June, 1856,* the iron is sixth in the order of tensile strength, and third in resistance to transverse strain. It is fifth in density.

3. The several systems of rifling may be described as follows:—

Mr B. Britten.—Gun rifled in 5 shallow grooves, one turn in 48 feet; projectile expanding, cylindro-conoidal, with lead envelop, attached by zinc; weight, empty, 47 lbs.

Mr Lynall Thomas.—Gun rifled in 7 shallow grooves, one turn in 18 feet; projectile expanding, cylindro-conoidal, with lead envelop, attached mechanically; weight, empty, 55 lbs.

Mr A. Jeffery.—Gun rifled in 7 circular grooves, one turn in 64 feet; projectile expanding, cylindro-conoidal, with lead envelop, attached mechanically; weight, empty, 45½ lbs.

Mr J. C. Haddan.—Gun rifled in 3 large circular grooves, with one turn in 25 feet; projectile non-expanding, but cast with wings or projections corresponding in form to the grooves in the gun; weight, empty, 51 lbs.: an expanding wad was generally used, but latterly Mr Haddan employed a non-expanding wooden sabôt.

Mr C. W. Lancaster.—Gun oval-bored, difference of axis, ·6 inch, one turn in 30 feet; projectile, cylindro-conoidal, but elliptical in section, and planed or turned with a skew corresponding to the bore; weight, empty, 45¾ lbs.

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* Cast-iron Experiments. Sessional Paper 497. 1856.

Commander R. A. E. Scott, R.N.—Gun rifled in three eccentric circular grooves, one turn in 48 feet; projectile, non-expanding, but cast with long wings or projections corresponding with the grooves on the gun, and set at the same angle to the axis; the bearing edges planed to the angle of rifling, and faced with zinc; their general form cylindrical, with hemispherical ends; weight, empty, 38¾ lbs.: an expanding wad is used.

The annexed Plate exhibits at one view the form of each projectile, with the principal particulars of the rifling of each gun.

4. The Committee have ascertained that in point of expense there is very little difference between any of these systems. They could, any of them, be applied to smooth-bored guns on a large scale, at a cost of not more than 10*s.* per gun for rifling, by extending the machinery in the Royal Gun Factories. It is stated by Mr Anderson that the system of Mr Bashley Britten would be the least expensive, and that of Mr Haddan the most expensive. The order of expensiveness is considered by Mr Anderson (Minute 3035) to be—

Mr B. Britten.	Mr C. W. Lancaster.
Mr A. Jeffery.	Commander Scott, R.N.
Mr L. Thomas.	Mr J. C. Haddan.

But they would all range between 7*s.* 6*d.* and 10*s.* per gun, for the cost of rifling, if executed in numbers, and this element is therefore immaterial.

5. When, however, the Committee compare them in respect to the expense of the projectiles, the difference is much more considerable.

The Superintendent, Royal Laboratory, has at their request estimated the cost *per thousand* of the common shells proposed for use by each inventor, and reports it as follows:—

	lbs.	£	*s.*	*d.*		lbs.	£	*s.*	*d.*
Commander Scott...	40 ...	184	9	0	Mr Jeffery	49 ..	295	5	0
M Haddan...........	47½ ...	193	9	0	Mr Britten	47½ ...	305	8	0
Mr Lancaster	49½ ...	194	4	0	Mr L. Thomas ...	54½ ...	484	2	0

The present smooth-bore 32-pr. shell, weighing 22 lbs., costs £87. 14*s.* per 1000, and the round shot £85. 17*s.* per 1000; to set against the more expensive projectile, however, there is a reduction of charge, which will be from 3 to 5 lbs., as against round-shot charges, but not more than 1 or 2 lbs., as against shells, the larger bursting-charge absorbing part of what is saved on the firing charge.

6. The Committee, on entering into this inquiry, were led to suppose that the several gentlemen who had been selected by the Secretary of State to rifle smooth-bored guns, had matured their views, and were prepared to carry out their respective systems at once, if allowed to do so. That such was also the impression conveyed to the Secretary of State may be inferred from the fact that the original orders only included 50 projectiles on each system, a number which might be sufficient to determine their relative accuracy in a match, but was quite insufficient to determine the various questions which soon arose. In a Report dated 25th April, 1860 (No. 762),

the Committee remarked, "It will be seen that some of the modes of rifling selected by the Secretary of State for this competitive trial have not been tried to this day, nor is there one instance in which the advocate or inventor of a system has presented himself to the Committee with his gun and projectiles in a state of readiness for a direct and final trial. Each gentleman has as yet required a number of preliminary experiments, to furnish himself with data on which to base his final arrangements. The Committee are far from imputing blame to them for this. It is next to impossible to determine many of the minor details on which the success of each method depends, without such experiments; but it will be seen, that as every step necessitates some delay, and some correspondence, the progress of the Committee must be retarded thereby." The original intention was, that out of the 50 shells supplied by each competitor, 10 should be at his disposal for preliminary trials, to fix the service charge, and the remaining 40 be fired at 5° and 10° of elevation, for comparative results. The instructions given to the Superintendent of Experiments at Shoeburyness, with reference to Mr Britten's gun (Appendix I. p. 342), the first which was ready, may be quoted for the whole of them.

7. The first 32-pr., rifled for Commander Scott, No. 9029, burst on 17th July, 1860, before that officer had settled the form or weight of his projectile, or his charge, and another gun was allowed to be rifled for him. This gun, No. 9127, reached Shoeburyness on 18th October, 1860, and is the one referred to in the following Table, which contains a comparative statement of the results obtained by firing the original 50 rounds, disregarding the 10 placed at each inventor's disposal, and also such other rounds as from change of projectile, alteration of charge, or some other cause, are not strictly comparable.

It will be seen by the dates that Mr B. Britten and Mr Jeffery were ready long before the others. The order of merit, judged by this first practice, is Haddan, Britten, Jeffery, Scott, Lancaster, Lynall Thomas.

TABLE I.

ABSTRACT OF PRACTICE OF COMPETITIVE RIFLED CAST-IRON 32-PR. GUNS, UNDER THE ORIGINAL PROGRAMME.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Name of competitor and gun.	Date.	Direction and force of wind.	No. of rounds.	Charge.	Mean weight of projectile.	Elevation.	Mean reduced time of flight.	Ranges.			Mean diff. of range.	Mean observed deflection.	Mean reduced deflection.	Area of rectangle.
								Min.	Max.	Mean.				
				lbs.	lbs.	°	"	yds.	yds.	yds.	yds.	yds.	yds.	yds.
Mr B. Britten	Nov. 16, 1859	→ 3	23	5·0	51·200	5	not obs.	1735	1918	1850	40·7	2·7	2·2	724
No. 8658.	...		19	...	...	10		2864	3196	3117	51·7	5·9	4·6	1860
Mr A. Jeffery	May 18, 1861	↘ 4	18	5·5	47·362	5	6·23	1706	1969	1886	57·6	10·2	3·0	1358
No. 8460	...		15	...	...	10	11·30	2985	3237	3129	55·4	31·6	6·1	2640
Mr Haddan	July 24, 1860	↗ 3	20	7·0	53·991	5	6·48	1970	2123	2034	32·7	7·8	3·9	991
No. 8640	„ 25, „		14	...	...	10	11·57	3117	3301	3228	36·6	22·6	5·1	1428

TABLE I.—*Continued.*

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Name of competitor and gun.	Date.	Direction and force of wind.	No. of rounds.	Charge.	Mean weight of projectile.	Elevation.	Mean reduced time of flight.	Ranges.			Mean diff. of range.	Mean observed deflection.	Mean reduced deflection.	Area of rectangle.
								Min.	Max.	Mean.				
				lbs.	lbs.	°	″	yds.	yds.	yds.	yds.	yds.	yds.	yds.
Com. Scott No. 9029.	Oct. 23, 1860	↖ 3	11	6·0	40·641	5	6·32	1880	2031	1975	37·5	7·5	2·8	891
	...		8	...	...	10	11·48	2967	3221	3136	80·8	7·4	7·6	5,598
Mr Lancaster No. 9050.	Jan. 21, 1861	↓ 2–3	20	6·0	48·016	5	not obs.	1964	2233	2096	66·3	9·9	7·3	3,749
	Feb. 4, ,,	↖ 3	20	...	...	10	12·02	3239	3540	3410	80·3	20·6	10·5	5,811
Mr L. Thomas No. 8641.	Feb. 23, 1860	1–2 ←	20	7·0	56·606	5	5·73	1655	2140	1916	124·9	7·8	6·8	5,941
	,, 24, ,,	,,	5	...	...	5	6·18	1758	2031	1933	70·0	12·2	3·1	2,331
	April 13, ,,	↙ 2	15	...	...	10	12·21	3160	3608	3375	105·8	72·8	15·8	13,345

8. In July 1860, the Committee recommended, in their Report No. 956 (Appendix V. 2, p. 354), that Mr Britten's two 32-pr. guns, No. 24 (A), rifled in May, 1856, in a 56 cwt. block, and No. 8658 (1), rifled for this competition in October, 1859, should be fired up to 300 rounds each, as well for endurance as for a better knowledge of their powers in respect to range and accuracy. This was approved by Lord Herbert (Min. 1770), and extended to the gun of 8-inch calibre in a 68-pr. block, rifled in December, 1859, No. 8282. It was subsequently extended to Commander Scott's and Mr Haddan's guns.

9. The second comparison was decided upon in consequence of the numerous alterations made in the course of the preceding trials by some of the competitors: alterations in the form of the shell, in their weight, in the charge employed, in the nature of the wads, cups, and lubricators, and in other details. The necessary stores were demanded on 8th February, 1861, but they were not all collected until August following, when the Committee attended at Shoeburyness to witness the practice. Each competitor was informed (Min. 3823) that he was at liberty to apply to the projectiles now to be tried every improvement suggested by his previous experience, provided he should not by so doing introduce any substantial novelty of principle or construction. The Committee also decided that in addition to the rounds to be fired with the several service charges proposed by the competitors, the whole of the guns should be fired with charges bearing the proportion of *one-tenth* to the weight of the shot (Min. 3355). Annexed is the programme (Appendix VI. p. 365) prepared for this trial, which took place on the 2nd, 3rd, and 5th of August, and the 24th, 25th, 26th, and 27th September, 1861. On the latter occasion, the two rifled 32-prs., previously referred to, Sir William Armstrong's, and the one on the French system, which were not originally competing guns, were fired for comparison, as was the smooth-bored or service 32-pr.

Table II.

ABSTRACT OF PRACTICE MADE WITH 32-PR. CAST-IRON GUNS RIFLED ON DIFFERENT SYSTEMS, WITH IMPROVED PROJECTILES, FIRING THEIR PROPOSED SERVICE CHARGES.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Name of competitor and gun.	Date.	Direction and force of wind.	No. of rounds.	Charge.	Mean weight of projectile.	Elevation.	Mean reduced time of flight.	Ranges.			Mean diff. of range.	Mean observed deflection.	Mean reduced deflection.	Area of rectangle.
								Min.	Max.	Mean.				
				lbs.	lbs.	°	″	yds.	yds.	yds.	yds.	yds.	yds.	yds.
Mr B. Britten No. 8658.	Aug. 2, 1861	5	15	5·000	50·37	2	2·84	738	1064	912	76·4	2·6	2·6	1,598
	„ 3, ...	6	15			5	6·06	1725	2084	1898	73·1	5·6	3·5	2,027
	„ 5, ...	4–5	12			10	11·56	3268	3467	3396	52·8	11·7	7·6	3,290
Mr A. Jeffery No. 8460.	„ 2, ...	„	15	5·500	47·94	2	2·97	1036	1124	1072	26·7	2·3	1·8	377
	„ 3, ...	„	15			5	6·43	2051	2238	2155	38·5	5·8	2·9	892
	„ 5, ...	„	12			10	11·95	3524	3666	3624	31·3	8·9	7·6	1,966
Mr Haddan No. 8640.	„ 2, ...	„	15	7·000	54·46	2	2·70	742	1093	980	51·1	3·1	3·0	1,328
	„ 3, ...	„	14	„		5	6·49	1821	2248	2137	65·9	8·1	7·0	4,008
	„ 5, ...	„	12	„		10	11·66	3377	3673	3503	67·7	35·7	9·2	6,418
Com. Scott ... No. 9127	„ 2, ...	„	9	6·125	43·76	2	3·26	1094	1151	1129	19·7	12·3	7·2	*415
Mr Lancaster No. 9050.	Sept. 24, ...	6	6	6·000	50·78	2	3·40	1023	1242	1175	62·4	6·7	4·9	2,568
	„ 25, ...		8			„	3·36	1017	1238	1137	61·3	2·6	2·6	1,261
	„ 25, ...	3	6			5	6·73	2059	2213	2136	51·2	6·8	6·8	3,481
	„ 26, ...		9			„	6·68	1970	2265	2128	57·2	22·2	4·1	2,043
	„ 26, ...	3	7			10	12·14	3350	3566	3466	65·9	61·5	9·5	5,913
	„ 27, ...	3	5			„	11·80	3103	3583	3333	172·6	31·8	15·2	28,326
French gun No. 9130.	„ 24, ...	„	7	5·500	64·69†	2	2·83	848	916	876	17·9	2·0	1·4	225
	„ 25, ...	„	8			„	2·81	828	916	873	19·0	3·5	2·4	355
	„ 25, ...	„	6			5	5·87	1641	1818	1721	50·8	7·8	5·0	2,542
	„ 26, ...	„	9			„	6·01	1664	1779	1730	28·9	4·9	3·2	540
	„ 26, ...	„	7			10	10·99	2949	3082	3014	51·7	8·3	6·1	2,965
	„ 27, ...	„	5			„	11·02	2888	3040	2963	39·0	25·8	5·3	1,066
	Mar. 9, 1862	„	15	5·500	65·54	2	2·82	768	882	827	24·2	2·03	1·55	218
	„ 9, ...	„	15			5	5·89	1584	1772	1672	45·6	6·19	2·33	849
	„ 9, ...	„	15			10	11·02	2742	3019	2891	84·6	19·9	4·40	2,962
Shunt gun ... No. 6842.	Sept. 24, 1861	„	7	5·500	56·351	2	2·93	917	1006	972	25·9	3·3	1·1	263
	„ 25, ...	„	8			„	2·91	898	974	934	16·2	2·8	1·4	199
	„ 25, ...	„	6			5	6·27	1832	2002	1940	63·0	8·2	2·5	1,595
	„ 26, ...	„	9			„	6·31	1883	2009	1952	38·7	20·0	2·7	918
	„ 26, ...	„	7			10	11·79	3238	3402	3331	50·3	55·8	7·5	3,560
	„ 27, ...	„	5			„	11·50	3158	3317	3222	42.0	38·3	4·3	1,953
		„												
Service 32-pr. smooth-bore, No. 7138.	„ 24, ...	„	7	10·000	31·250	2	3·76	1267	1373	1300	38·0	1·5	1·4	514
	„ 25, ...	„	7			„	3·41	1118	1311	1154	20·0	4·7	2·3	443
	„ 25, ...	„	6			5	7·05	1964	2174	2033	55·2	24·2	9·6	5,296
	„ 26, ...	„	9			„	7·12	1945	2281	2038	84·0	11·4	8·9	6,571
	„ 26, ...	„	7			10	12·10	2814	3126	2957	103·6	51·5	50·7	49,644
	„ 27, ...	„	5			„	11·54	2734	3079	2848	92·8	33·5	36·2	36,494

* This gun burst at the tenth round.

† These projectiles had been made for a gun with right-handed twist, and in firing them from the present gun the iron side of the stud became the bearing side.

10. Tables I and II speak for themselves, except in respect to the last four columns, which may require some little explanation.

Column 12, headed "Mean difference of range," is the arithmetical mean of the quantities by which each individual shot differs, in point of range, from the mean of the whole. Its amount is therefore a measure of the irregularity of range of the gun.

Column 13, headed "Mean observed deflection," is the mean of all the deviations from the line of fire, whether to right or left.

Column 14, headed "Mean reduced deflection," is the mean of the deviations, referred, not to the line of fire, but to the mean direction of all the shots; thus eliminating *derivation* and other causes influencing them all alike; also wind, so far as it affects direction, but not as affecting range. It was originally intended to have reduced all the deflections to their value at the mean range, and this would have been necessary if they had all been referred to one line of fire; but each having been referred to its own line of fire, the comparison is fair; and the mean deviations are the same as if this somewhat laborious reduction had been made.

Column 15, headed "Area of rectangles," is the area of that rectangle into which, by calculation of probabilities, one-half of the shot at each distance may be expected to fall.* The area is perhaps the most convenient datum for tabular comparison; but the length and width are given in Table VIII., p. 335.

11. It will be observed, that as the several competitors were not limited in the weight of the projectile they might employ with a rifled cast-iron 32-pr. gun, or in their charge, they adopted charges which bear very different proportions to the weight of the shot: the ranges obtained, therefore, under the same degrees of elevation, are not directly comparable. The charges, in order of relative amount, are as follows:—

TABLE III.

Name.	Charge. C		Shot weight. P	$\frac{C}{P}$
	lbs.	oz.	lbs.	
Smooth-bore 32-pr.	10	0	31·4	·312
			Shell loaded.	
French system	5	8	64·7	·085
Shunt rifle	5	8	56·3	·098
Britten	5	0	50·4	·099
Jeffery......................	5	8	47·9	·115
Lancaster	6	0	50·8	·118
Service B.L. 40-pr.	5	0	40·5	·123
Lynall Thomas	7	0	56·6	·124
Haddan	7	0	54·5	·128
Scott	6	2	43·7	·140

To obtain a direct comparison of range, it was decided to fire the whole with equal relative charges of one-tenth the shot's weight. The results are contained in the following Tables:—

* See a Paper by Captain A. Noble, in the "Occasional Papers" of the Royal Artillery Institution, Vol. I. p. 173.

Table IV.

ABSTRACT OF PRACTICE MADE WITH 32-PR. CAST-IRON GUNS, RIFLED ON DIFFERENT SYSTEMS, IN COMPARISON WITH AN ARMSTRONG 40-PR. AND A SMOOTH-BORED 32-PR.; THE WHOLE FIRING A UNIFORM PROPORTIONATE CHARGE OF ONE-TENTH.

1	2	3	4	5	6	7	8	9	10	11	12	13	14
Name of competitor and gun.	Date.	Direction and force of wind.	No. of rounds.	Charge.	Mean weight of projectile.	Elevation.	Mean reduced time of flight.	Ranges.			Mean diff. of range.	Mean observed deflection.	Mean reduced deflection.
								Min.	Max.	Mean.			
				lbs.	lbs.	°	″	yds.	yds.	yds.	yds.	yds.	yds.
40-pr. breech-loader, No. 24	Oct. 11, 1861	5–6	5	4·106	41·06	2	3·40	955	1073	1033	32·8	2·4	1·2
	”		5			5	6·24	1831	1950	1886	41·2	2·1	·7
	”		5			10	11·38	3222	3354	3262	37·0	3·0	1·9
Mr B. Britten No. 8658	Aug. 6, 1861	3–4	5	5·038	50·38	2	3·18	1083	1125	1103	13·8	1·7	1·5
	”		5			5	6·44	2045	2197	2123	41·6	6·8	3·2
	”		5			10	11·52	3425	3523	3465	24·4	11·5	6·5
Mr A. Jeffery No. 8460	Aug. 6, 1861	do	5	4·791	47·91	2	2·94	945	1067	1018	29·6	2·3	2·1
	”		5			5	6·14	1958	2053	1991	25·2	7·8	3·3
	”		5			10	11·62	2896	3440	3282	154·4	24·0	12·8
Mr Haddan. No. 8640	Aug. 6, 1861	do	5	5·450	54·50	2	2·70	837	944	905	31·8	2·4	1·3
	”		5			5	5·70	1618	1888	1752	104·4	6·2	5·1
	”		5			10	10·78	3037	3250	3109	56·4	22·9	4·8
Shunt ……… No. 6842	Oct. 11, 1861	5–6	1*	5·635	56·35	2	…	…	…	1093	…	5·3	…
Mr Lancaster No. 9050	Oct. 11, 1861	do	5	5·078	50·78	2	3·04	967	1087	1032	41·8	2·4	2·6
	”		5			5	6·44	1961	2097	2032	34·2	11·6	11·3
	”		5			10	11·48	3113	3464	3270	126·2	12·2	10·9
French …… No. 9130	Mar. 9, 1862	do	5	6 554	65·54	2	2·76	822	909	861	32·0	3·40	·4
	”		5			5	6·20	1817	1877	1839	19·5	8·90	1·2
	”		5			10	12·07	3233	3308	3274	27·7	25·90	·3
Service 32-pr. smooth-bored No. 7138	Oct. 11, 1862	5–6	5	3·125	31·25	2	2·80	653	770	721	34·8	1·5	1·1
	”		5			5	5·32	1186	1351	1302	68·4	3·7	3·7
	”		5			10	8·88	1770	2160	2029	107·0	12·4	12·4

12. On the completion of the practice, the Committee took steps to ascertain the initial velocity of the projectiles of each gun, by means of Navez's electro ballistic apparatus. The results are contained in the following Table, to which is added the velocity as observed or deduced from the observations for an equal relative charge of one-tenth.

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* Gun burst at 2nd round, or 327th in all.

TABLE V.

Name of competitor and gun.	No. of rounds.	Charge.	Projectile. Weight.	Projectile. Diameter.	Velocity 90 ft. from muzzle.	Velocity at muzzle. Service charge.	Velocity at muzzle. Charge, $\frac{1}{10}$th	Relative strength of powder, as tested by 12-pr. Armstrong gun.¶
		lbs. oz.	lbs.	in.	ft.	ft.	ft.	
Britten*	5	5 0	50·36	6·24	1199·7	1209·2	1213·5	1170
Jeffery	5	5 8	48·06	6·26	1253·0	1263·6	1181·2	1170
Haddan	5	7 0	54·20	6·19	1267·9	1277·1	1123·7	1170
Scott†	...	...	...	...	...	...	...	...
Lancaster	5	6 0	51·00	{6·88 / 6·32}	1234·4	1246·0	1149·0	1170
Thomas	5	7 0	56·92	6·25	1384·0	1395·0	1277·0‡	1248
French	5	5 8	64·68	6·36	1052·4	1059·0	1148·4	1248
Shunt†	6	5 8	55·25	6·32	1161·9	1170·1	1172·7‡	1248
[1] Service 32-pr.	10	10 0	31·60	6·166	1653·7	1690·0§	...	...
[2] " "	5	3 2	31·37	6·166	977·5	...	993·7‡	1195
[2] " "	5	2 7	24·31	6·164	968·0	...	988·8‡	1195
[1] Armstrong's 40-pr. No. 544	5	5 0	41·25	4·75	1190·3	1197·5	...	1248
[2] " " "	5	5 0	40·5	4·75	1219·7	1227·3	...	1248
[2] " " "	5	4 0	40·5	4·75	1076·2	...	1081·4‡	1248
[1] Armstrong's naval 40-pr., No. 184.‖	5	5 0	41·0	4·75	1168·5	1174·8	1050·7	1248

[1] Solid shot. [2] Common shell.

* Min. 5547. † Burst before this experiment. ‡ Observed velocities.

§ Determined by Captain A. Noble. ‖ Min. 7607.

¶ The last column contains the velocities in feet per second of 12-pr. shot, fired from the standard gun on each occasion, with the same powder as that of the gun named.

13. As a sequel to the whole, and as affording a far more satisfactory test of endurance than can be obtained by firing extra charges, it was decided, with the approval of the Secretary of State (Min. 4208), to continue the practice with those guns which remained serviceable until they should burst, using the service charge and service weight of projectile. Shot were substituted for shells in the case of Messrs Lancaster and Jeffery, for the sake of economy, and the guns were fired into the proof-butt, Woolwich.

TABLE VI.

Min.	Gun.	Charge.	Weight of shot or shell.	Previously fired.	Fired at proof-butt.	Total endurance.
		lbs. oz.	lbs.			
7054	Britten	5 0	50·00	363	1123	1486*
6234	Jeffery	5 8	47·00	113	250	363
7738	Lancaster	6 0	50·00	200	1800	2000*
7071	Haddan	7 0	54·12	125	90	215

* Not burst.

14. The Committee have now placed the Secretary of State in possession of all the material facts elicited by the comparison of cast-iron 32-prs. rifled on different systems, and will proceed to draw the conclusions which they think warranted by them.

The systems of rifling tried may be reduced to five, viz.:—

(1) For expanding lead-coated projectiles, represented by the guns of Messrs B. Britten, A. Jeffery, and Lynall Thomas.

(2) For projectiles with ribs or projections faced with zinc, with long bearings—Commander Scott's, and the shunt 32-pr., which, however, it must be remembered, was not prepared for this competition (see § 1), and fired shells of a weight calculated for a wrought-iron (not a cast-iron) gun of this calibre.

(3) For projectiles with studs or projections faced with zinc, having short bearings—the French system.

(4) Projections not faced with zinc, with short bearings—Mr Haddan.

(5) The oval bore.

Mr Haddan and Commander Scott use a wad or sabôt of wood or papier-maché, and tried a variety of patterns. Both these gentlemen lay great stress on an operation of centering, supposed to be secured by the form of the grooves, and of the bearing edges of the flange or projection on the projectile, and which is intended to prevent any deviation of the axis of the shot from that of the gun. This, however, is equally sought in the shunt system and the French system, and to judge by the accuracy of the shooting, appears to be more perfectly attained by them.

15. These systems may be compared under the following heads:—

(1) Safety and durability of the gun, which includes absence of liability in the projectile to jam in the bore.

The Committee rank them in the following order:—

1	Britten, least liable.	5	French.*
2	Jeffery.	6	Haddan.
3	Thomas.	7	Scott.
4	Shunt.	8	Lancaster, most liable.

For projectiles of the same weight, the same diameter, and fired with the same charge, the strain upon the gun may be assumed to vary directly as the *sine of the angle of rifling*, but will be in a certain degree dependent also on the amount of friction between the surfaces in contact; thus, it is least for copper rubbing on iron, and greatest for one iron substance rubbing on another. The relative order will be copper, zinc, lead, iron.

* The gun rifled on the French system burst subsequently to the date of this Report, on the 14th April, 1863, at the 107th round.

The angles of rifling, and bearings of the different systems, are as follows:—

TABLE VII.

Name.	One turn in calibres.	Angle.	Sine of angle.	Bearing.	Approximate area of	
					Bearing surface.	Guiding edges.
		° ′			sq. in.	sq. in.
Jeffery	120	1 30	·0262	Lead	26·2	2·1
Britten	90	2 0	·0349	Lead	20·0	1·0
Scott	90	2 0	·0349	Zinc	19·5	3·9
French	*	*	*	Zinc	4·7	0·6
Lancaster	56	3 13	·0561	Iron	3·75	0·0
Haddan.........	47	3 49	·0666	Iron	8·4	1·0
Lynall Thomas	32	5 17	·0921	Lead	34·6	1·9
Shunt...........	28	6 24	·1115	Zinc	7·7	2·4

The spiral of the French gun is increasing, beginning with 0 at the seat of the shot, and ending with 2° 53′ at the muzzle.

With the foregoing we must, however, take into consideration any special feature in the form of the projectile, or the mode by which rotation is impressed upon it, by which friction is augmented, or the maximum strain prolonged. Mr Jeffery's projectiles differ from Mr Britten's in having a considerable cup at the base, which is expanded by the gas, and must, by the pressure of the side against the bore, augment the friction. In Mr Lancaster's system, the major-axis of the ellipse, when the projectile begins to rotate, has a tendency to overrun the spiral of the gun, and to pinch, or act as a wedge to burst it. The area of bearing surfaces in the above Table is the area of so much of the lead as is upset or expanded into the grooves in Britten's and Jeffery's systems; of the zinc patches, zinc ribs, or other projections, in the other systems; and the area of the guiding edges is the area of such a length of the sides of the grooves as is at each moment in contact with these patches or projections. In the oval bore, where the bearings are 3·75 inches long, it is assumed that from compression of the ellipse there is actual contact for a width of half an inch at each extremity of the major-axis. It appears to show generally that the French shot got through the bore with the least resistance of friction, Mr Haddan's being second in order. The Committee, however, prefer the facts furnished by the bursting of guns, to any conclusions based on mechanical considerations, which involve many uncertainties, and many discordant elements. These facts are, 9 cast-iron guns have been rifled on Mr Britten's system, only one has exhibited a want of endurance. A gun of 18-pr. bore (5·29 inches), in 32-pr. block, No. 9087, burst on 5th April, 1860, at the 53rd round. It was firing a shot of 34 lbs., with a charge of 6·5 lbs., and Mr Britten has shown that, under the circumstances, the strain was more than double that of his competitive system.

(2) The competitive gun, No. 8658, has stood 1286 service rounds.†

† Since increased to 1486 rounds.

(3) The 56 cwt. 32-pr., No. 24 (A), rifled in May 1856, has stood 345 rounds.

(4) The 58 cwt. 32-pr., No. 2339 (Walker's, Min. 3087), especially rifled, to be tested for endurance, resisted to the 54th round (Min. 6363), viz.:—

Charge, 5·5 lbs.;	10 rounds,	shot,	48 lbs.
„	10	„	72 „
„	10	„	96 „
„	10	„	115 „
„	10	„	140 „
„	4	„	165 „
	54	Burst 26th March, 1862.	

(5) Another 58 cwt. 32-pr., No. 8541, Lowmoor (Min. 6885), similarly rifled, resisted to the 57th round, viz.:—

Charge, 5·5 lbs.;	10 rounds,	shot,	48 lbs.
„	10	„	72 „
„	10	„	96 „
„	10	„	120 „
„	10	„	144 „
„	7	„	163 „
	57	Burst 18th June, 1862.	

(6) A 95 cwt. 68-pr., No. 6095 (Walker's, Min. 6489), especially rifled, to be tested for endurance, resisted to the 60th round, viz.:—

Charge, $7\frac{1}{2}$ lbs.;	10 rounds,	shot,	90 lbs.
„	10	„	135 „
„	10	„	180 „
„	10	„	225 „
Charge, $7\frac{1}{2}$ lbs.;	10 rounds,	shot,	270 lbs.
„	10	„	315 „
	60	Burst 17th April, 1862.	

(7) Another 95 cwt. 68-pr., No. 6439 (Lowmoor, Mins. $\frac{3087}{6489}$), similarly rifled, resisted to the 60th round, and remains apparently serviceable, as there is no appearance of fissures round the vent.*

(8) A third 68-pr., No. 8282, has fired 300 service rounds, charge generally 7·5 lbs., projectile 87 lbs., and is uninjured.

(9) A fourth 68-pr. block, with 32-pr. bore, No. 1348 (Min. 6490), has fired 110 rounds.

16. *Relative accuracy.*—The order of accuracy in the two competitive trials was—

First Trial.		Second Trial.	
———	Jeffery.	French system.	Britten.
———	Scott.	Shunt.	———
Haddan.	Lancaster.	Jeffery.	Lancaster.
Britten.	Thomas.	Haddan.	———

The bore of the 32-pr. being 17 calibres long, these guns may be best compared with the naval or shorter Armstrong 40-pr., the bore of which is 17·7 calibres long. The Committee subjoin the results obtained with two guns of this description, upon occasions of experimental trial. The relative charge is greater than that of any of the competitors for rifling cast-iron guns, except Mr Haddan and Commander Scott.

* No. 6439 subsequently fired 10 rounds, cylinders 369 lbs.; 10 rounds, cylinders 402·75 lbs., and burst the 81st round with a cylinder of 450 lbs. Minutes 7054—7450.

Table VIII.

ABBREVIATED RECAPITULATION OF RESULTS IN TABLES I. AND II., FOR COMPARISON OF ACCURACY, ARRANGED ACCORDING TO RELATIVE MAGNITUDE OF THE CHARGE USED.

Name of competitor and number of gun.	Date.	Charge. $\frac{C}{P}$	No. of rounds.	Elevation.	Mean range.	Mean difference of range.	Mean reduced deflection.	Rectangle containing half the shots. Length.	Width.
				°	yds.	yds.	yds.	yds.	yds.
Short 40-pr., of original pattern Min. 4346.	June 17, 1861	·123	10	2	950	16·5	·53*	48·2	1·9
	”	·124	10	2	982	13·0	·69†	38·0	2·1
	”	·123	10	5	1950	9·9	1·03*	29·0	3·6
	”	·124	10	5	1977	16·4	·84†	48·0	2·5
	”	·123	10	10	3413	33·3	2·49*	97·6	7·3
	”	·124	10	10	3423	18·9	2·01†	56·7	6·6
Short side breech-loading 40-pr. Min. 7634.	Oct. 10, 1862	·123	20	2	1067	11·5	·79*	32·2	2·2
	”	·123	20	5	2030	19·2	1·36*	52·5	3·8
	”	·123	20	10	3330	43·8	1·76*	118·9	4·9
French system ...	Sept. 24, 1861	·085	7	2	876	17·9	1·4	54·8	4·1
	”	”	8	2	873	19·0	2·4	57·2	6·2
	April 9, 1862	”	15	2	827	24·2	1·55	68·3	3·2
	Sept. 25, 1861	”	6	5	1721	50·8	5·0	160·9	15·8
	”	”	9	5	1730	28·9	3·2	85·7	6·3
	April 9, 1862	”	15	5	1672	45·6	2·33	128·7	6·6
	Sept. 26, 1862	”	7	10	3014	51·7	6·1	157·7	18·8
	”	”	5	10	2963	39·0	5·3	128·4	8·3
	April 9, 1862	”	15	10	2891	84·6	4·40	238·9	12·4
Shunt	Sept. 24, 1861	·098	7	2	972	25·9	1·1	79·6	3·3
	Sept. 25, 1861	”	8	2	934	16·2	1·4	48·5	4·1
	”	”	6	5	1940	63·0	2·5	199·4	8·0
	Sept. 26, 1861	”	9	5	1952	38·7	2·7	114·7	8·0
	”	”	7	10	3331	50·3	7·5	154·8	23·0
	Sept. 27, 1861	”	5	10	3222	42·0	4·3	138·5	14·1
Britten	Nov. 16, 1859	·099	23	5	1850	40·7	2·2	112·1	6·1
	”	”	19	10	3117	51·7	4·6	144·0	12·9
	Aug. 2, 1861	”	15	2	912	76·4	2·6	216·0	7·4
	”	”	15	5	1898	73·1	3·5	206·8	9·8
	”	”	12	10	3396	52·8	7·6	151·6	21·7
Jeffery...............	May 18, 1861	·115	18	5	1886	57·6	3·0	160·9	8·4
	”	”	15	10	3129	55·4	6·1	154·0	17·1
	Aug. 2, 1861	”	15	2	1072	26·7	1·8	75·4	5·0
	”	”	15	5	2155	38·5	2·9	108·9	8·2
	”	”	12	10	3624	31·3	7·6	90·2	21·8
Lancaster	Jan. 21, 1861	·118	20	5	2096	66·3	7·3	184·1	20·4
	”	”	20	10	3410	80·3	10·5	223·1	26·1
	Sept. 24, 1861	”	6	2	1175	62·4	4·9	164·6	15·6
	”	”	8	2	1137	61·3	2·6	161·7	7·8
	”	”	6	5	2136	51·2	6·8	161·9	21·5
	”	”	9	5	2128	57·2	4·1	169·8	12·0
	”	”	7	10	3466	65·9	9·5	202·5	29·2
	”	”	5	10	3333	172·6	15·2	568·8	49·8
Lynall Thomas ...	Feb. 23, 1860	·124	20	5	1916	124·9	6·8	346·8	17·1
	”	”	5	5	1933	70·0	3·1	230·8	10·1
	”	”	15	10	3375	105·8	15·8	299·3	44·6
Haddan	July 24, 1860	·128	20	5	2034	32·7	3·9	90·7	10·9
	July 25, 1860	”	14	10	3228	36·6	5·1	101·5	14·7
	Aug. 2, 1861	”	15	2	980	51·1	3·0	155·6	8·6
	Aug. 3, 1861	”	14	5	2137	65·9	7·0	200·4	20·0
	Aug. 5, 1861	”	12	10	3503	67·7	9·2	243·4	26·4
Scott	Oct. 23, 1860	·140	11	5	1975	37·5	2·8	108·7	8·2
	”	”	8	10	3136	80·8	7·6	243·4	23·0
	Aug. 2, 1861	”	9	2	1129	19·7	2·4	58·5	7·1

* Shot. † Common shells.

17. It is apparent that none of the cast-iron 32-pr. guns rifled, approach the Armstrong naval 40-pr. in precision; but the Committee consider that it would be too much to attribute this inferiority altogether to the systems on which those guns were rifled. They have more than once pointed out, that to compare systems of rifling properly, the guns must be of the same length, and both guns and projectiles be made with equal mechanical perfection and finish. The former condition (equality of length) is in this instance answered, but not the latter. However, they are of opinion that these muzzle-loading guns, however made, would not have equalled the Armstrong breech-loader in uniformity or precision. It is remarkable that the gun rifled on the French system, which comes out very well in the comparison, made rather better practice with a first supply of shells, which were without zinc facing to the bearing side of the patch, than with those which were subsequently made for the gun.

18. *Efficiency of projectile* (Min. 5547).—The relative efficiency of solid shot must be measured by the velocities given by equal charges. Mr Britten appears to have a decided advantage here over the other competitors. The same remark applies to common shells, but must be combined with a large capacity for the bursting charge.

The actual bursting charges are as follows:—

TABLE IX.

Name.	Weight of shell, empty.	Bursting charge.		Relative weight of bursting charge of shell.
	lbs.	lbs.	oz.	
Scott	38·8	4	13	·124
Shunt	50·5	5	13	·115
French	59·4	5	5	·090
Lancaster	45·8	4	7	·076
Britten	46·9	3	7	·073
Haddan	51·1	3	6	·065
Jeffery	45·4	2	8	·055
Lynall Thomas	55·3	1	5	·025

Commander Scott's form is the most advantageous for a shell in respect to capacity, and Mr Lynall Thomas's the least so; considering that if cast-iron guns are rifled, they must be used with low charges, and will generally fire common shells, the Committee give precedence, in respect to the efficiency of the projectile, to Commander Scott. It will be observed that they have placed this merit third in rank, because insufficiency of velocity or of bursting charge cannot be alleged against any of the systems; the capacity of the smallest shell is equal to that of the 8-in. common spherical shell, and the initial velocity of the whole is equal to that of the service rifled guns. Commander Scott's projectiles have the further merit of being of convenient exterior form, easy to pile, but little liable to injury, and simple in manufacture, being only exceeded in this respect by Mr Haddan's. Both require a touch of the planing tool on the bearings; the latter requires nothing more, but Commander Scott's bearings are previously zinced. On the other hand, both require to be used with a wad or sabôt, which is much to be avoided.

19. *Cost of projectiles.*—This has been stated in a previous paragraph. The quantity of lead on one of Mr Britten's shells is about 7 lbs. 12 oz.; on one of Mr Jeffery's considerably more, namely, 11 lbs. 3 oz. The adhesion of the lead is satisfactory in both plans, but Mr Britten's projectiles are the least susceptible of injury, the base being protected by the wooden disc, which expands the lead into the grooves. These projectiles do not require turning, which is required by Mr Lancaster's, or planing, which is required by Mr Haddan's and Commander Scott's; the two last are, however, on the whole, the least expensive of those tried.

20. *Adaptation for firing round shot.*—The system which is in itself best adapted for firing round shot is Mr Lancaster's; but to judge by results with the 9-pr. oval bore 4·2-in. gun (p. 363), it is extremely inaccurate with them, so much so that they could not be used with any advantage at ranges beyond 1000 yds. The Committee have found the shallow grooves of Britten and Jeffery, although perhaps somewhat more liable to injury, much more favourable to this practice; they only affect the accuracy by increasing the space available for the escape of gas, which might, if necessary, be met by a small increase of charge; generally, the plan which leaves the largest portion of the cylinder untouched, will be the best in this point of view, provided there is nothing in the form of groove peculiarly susceptible of injury from an iron shot.

The following Table contains comparative practice in August 1861, with a smooth-bore 32-pr., and a shallow-grooved rifled gun (Britten's), both firing round shot, with the service charge of 10 lbs. Elevation by spirit-level, and the guns 17 ft. above the plane.

TABLE X.

Min. 7302.	Number of rounds.	Elevation.	Time of flight.	Ranges. Min.	Ranges. Max.	Ranges. Mean.	Mean difference of range.	Mean observed deflection.	Mean reduced deflection.
		°	"	yds.	yds.	yds.	yds.	yds.	yds.
Smooth-bored 32-pr.... No. 10,297.	20	2	3·40	1027	1329	1146	51·7	8·1	2·6
	20	5	not recorded	1823	2222	1994	70·8	9·8	8·9
Shallow-grooved 32-pr. No. 24.	20	2	3·59	1063	1260	1172	32·6	7·8	2·7
	20	5	6·59	1821	1988	1882	24·9	5·8	5·8

The result is decidedly in favour of the rifled gun. This is more than could be generally expected, but it makes it probable that little or no disadvantage would accrue from the grooving.

The Committee have not tried it with any other system, but see nothing in the different forms of groove to make a material difference in their liability, or that of the lands between them, to receive injury. The sectional area of the bore of the 32-pr. gun is 31·92 square inches; the area of the section

of a shot of mean gauge is 29·91 square inches, leaving a mean space for the escape of gas of 2·01 square inches, or ·063 of the area, to which would be added, by the grooving under the different systems, the following quantities nearly :—

TABLE XI.

Name of competitor.	Added by grooving.	Total windage for round shot.	Name of competitor.	Added by grooving.	Total windage for round shot.
	sq. in.			sq. in.	
Lancaster ...	2·955	4·96	Jeffery	1·14	3·15
Haddan......	1·37	3·38	Britten	1·00	3·01
French	1·36	3·37	Shunt	·67	2·68
Thomas	1·26	3·27	Scott	·53	2·54

The great disadvantage of the oval bore in this particular is apparent at once; it has, however, the merit of not being liable to any injury by the use of round shot.

21. The Committee conceive that the invitation to certain gentlemen to compete against one another, to produce the best method of rifling cast-iron guns, renders it necessary that they should specify who has in their opinion been most successful, whether his plan is or is not carried out. They have no hesitation in awarding the first place to Mr Bashley Britten, on the ground of the comparatively little strain on the gun, caused by projectiles on his system, with the moderate charge he advocates, as shown by the great endurance of a large number of guns rifled for him, and by the high initial velocity attained. In point of accuracy, this system appears to be on the whole equal to that of any other of the competitors, although occasionally liable to wild shots. It is inferior to the shunt mode of rifling, and to the French system.

22. The Committee reject Mr Jeffery's system, considering the form of rifling as inferior to Mr Britten's, and because this gun, and several others rifled on the same system, have shown a want of endurance.

The competitive rifled 32-pr., No. 8460, burst at the 363rd round. (Exptl. No. 92).

A gun of 24-pr. bore, in 56-pr. block, rifled in 1856, burst in 29 rounds, with charge of 13·5 lbs., shell 53·5 lbs.

Three of the guns of small calibre, rifled in 68-pr. blocks by order of Major-General Peel in 1859, have burst; although, like the 56-pr., of extraordinary weight in comparison with their calibre, viz :—

No. 94, 6·375 in. calibre, twist $\frac{1}{130}$, burst 5th February, 1862 (Min. 6234), at the 40th round; charge, 8 lbs.

No. 95, 5-in. calibre, twist $\frac{1}{30}$, burst 1st August, 1862 (Min. 7186), at 121st round; charge, 5 lbs. 4 oz. This was originally a 3-in. gun, then bored up to 4 in., and subsequently to 5 in.

No. 96, 6·375 in. calibre, twist $\frac{1}{30}$, burst 5th May, 1862 (Min. 6131), at the 20th round; charge, 8 lbs.

These guns were of untried mixtures, and therefore possibly of inferior strength to guns made of mixtures of established character.

The Committee reject Mr Jeffery's projectiles, as requiring about one-fourth more lead than Mr Britten's, and holding less powder. The mode of attachment is less simple. They conceive the cavity at the end to be unnecessary and to be injurious, causing additional friction of the rear of the shot against the bore. They are also more susceptible of injury, not having the protection of a disc of wood at the base.

23. The Committee reject Mr Haddan's system, considering the proposed projectile much too heavy, and the proposed charge too large. It is also a disadvantage that it requires a wad or sabôt, which, in the form last used, was a disc of hard wood, weighing 1 lb. 5 oz., and would in practice be much objected to. The gun burst at the 215th round.

24. The Committee reject Commander Scott's system, because both guns showed a great want of endurance, and made indifferent practice. No. 9029 burst after 78 rounds; No. 9127 after 309 rounds; and they consider that there is a tendency of the shot to override the grooves. Commander Scott has contended that the guns were originally badly bored and were badly rifled. The Committee, on full inquiry, believe that there is no sufficient ground for this complaint; but, if well founded, it tends to show that this system requires greater nicety than other systems, which is a disadvantage in a proposal to convert smooth-bored guns. The necessity of using a wad is also a disadvantage. Much stress is laid by Commander Scott on an alleged straightness of ricochet peculiar to his projectiles. The Committee do not consider this property to be one of much importance, if even an advantage in this respect could be clearly established. The ricochet of rifled projectiles on land or water will always be too irregular to allow the second graze to be relied on for any service.

25. The Committee reject Mr Lancaster's gun for its irregular practice and inferiority for firing spherical projectiles. The fact that the gun No. 9050 has stood 2000 service rounds is, so far as it goes, highly favourable to the system in point of endurance; but it may be, and as the Committee believe is, chiefly attributable to the accident of a block of very exceptional quality having been oval-bored. It cannot be accepted as at all comparable to the evidence afforded by the endurance of 7 out of 8 blocks rifled for Britten's projectiles. A ninth has not been sufficiently tested to give evidence either way.

26. It remains to answer a question of much greater public importance than the relative success of different competitors, in their endeavours to meet the requirement of the Secretary of State; namely, whether any of their plans, or of the others tried with them, are suitable for adoption, and whether it is desirable to introduce cast-iron rifled guns for land or sea service. The Committee must avow a considerable mistrust of cast-iron of the quality turned out by English foundries, as material for rifled cannon, except with such restrictions as to charge as would limit them to the uses

of howitzers. There is proof that cast-iron guns occasionally possess ample strength. This is evidenced by the Lowmoor gun, oval-bored for Mr Lancaster, having resisted 2000 service rounds, and by Mr Britten's having stood 1486 (1st April, 1863); but the ordinary inequality of endurance, which causes some cast-iron smooth-bored guns to be condemned much earlier than others, must attach to the material in any form, and in rifled guns would produce a greater number of failures, and failures at an earlier stage, in proportion to the greater strain upon them.

The Committee have had no opportunity of trying guns made of charcoal-iron. They have very little confidence in proposals to strengthen cast-iron by external envelopes of steel or wrought-iron. The process of gradual destruction commences with small fissures round the vent; and when these have proceeded to a certain extent, the entry of the gas at an enormous pressure tends to rend the metal as if by a wedge. No external envelop will prevent this action: its only advantage here seems to be to make the effect less destructive. The external envelop adds to the strength of the cast-iron gun to resist a strain, when there are no fissures and no rending action; but this is not the ordinary cause of guns bursting. Guns condemned as unserviceable are almost invariably condemned for the state of the metal round the vent, and explosions must be generally attributed to that cause. Mr Britten has shown that when his gun of 5·29-in. bore, in a 32-pr. block, was burst, it was under a strain exceeding that in the 32-pr. rifled gun, in the ratio of 940 tons to 416 tons (Min. 5547); and by the same method of comparison it may be shown that the relative strain under the different systems, measured by the average pressure as far as the trunnions, multiplied into the resistance, or weight moved per square inch of section, was as follows: —

TABLE XII.

Name.	Relative strain.	Rounds fired.	Remarks.
Britten	620	1486	Not burst.
Jeffery	708	363	Burst.
Scott	720	309	Burst.
Lancaster	787	2000	Not burst.
Shunt	798	327	Burst.
French	923	104	Not burst.
Haddan	1171	215	Burst.

There appears to be no good reason why the projectiles should be heavier, or fired with a heavier charge, under one system than under another: the material fact is, that Mr Jeffery's gun, Commander Scott's, Mr Haddan's, the French, and the shunt gun, burst at a stage out of all proportion earlier than the apparent excess of strain on them would warrant. It will be observed, however, that Mr Britten's results are obtained at a cost of much less strain on the gun than those of either of the other plans, and the Committee believe that if circumstances of urgency warrant the rifling of cast-iron, it may be done on this system with less risk than on any other they are at present acquainted with. They trust that no such urgency will arise, and that so precarious a material will not come into use for rifled artillery.

27. Such guns, would, however, if made, be perhaps capable of firing round shot, common shell, shrapnel shell, grape or case shot, with a reduction of the present service charge;* and apparently with little or no loss of accuracy. They would fire an elongated common shell, containing three times the bursting charge of the round shell, and weighing twice as much, with half the service charge, or perhaps less; but attaining ranges exceeding those of the service round shot, and possessing much greater precision. For those artillery services in which low charges are necessarily employed,—such as enfilading short fronts, dismounting ordnance behind traverses, or breaching sunken defences,—they would probably equal wrought-iron ordnance.

28. It will have been observed in the perusal of the preceding Report that the elements of rifling are at least six in number, and admit of endless combinations. The form of the bore; the form of the grooves; the number of grooves; the twist; the proportion of the weight of the shot to that of a round shot of the same calibre, or, in other words, the calibre for a given weight of projectile and the weight of projectile for a given calibre; the nature and arrangement of the studs, ribs, or other agency, by which the projectile is made to receive its rotation from the grooving. To which may be added, as very materially affecting the result, the length of the gun, the weight of the gun, and the proportionate charge. It is exceedingly desirable to secure comparable results, by placing certain practical restrictions on those who bring forward rifled guns for trial, to determine, for example, the natures or classes to which the guns are to be referred; such as field guns, garrison guns, naval broadside guns, naval pivot guns, naval cupola guns, or guns to be mounted on turn-tables in any position, guns for coast defences, &c.: to assign a limit of weight and length not to be exceeded, and perhaps also—although this is less frequently called for—a weight which must be given for the sake of the carriage: to assign the calibres, the limits of weight for the projectiles proper to either class, and the maximum charge to be allowed. These would be restrictions of the liberty hitherto extended to inventors, but they would in time secure a valuable body of results. Under the present system, as exemplified by the trial now reported, the Government, in its desire to leave individual talent full scope for its exertion, scarcely exercises control enough to secure public objects.

J. St GEORGE, Brigadier-General,
President.

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* The reduction of the 32-pr. charge from 10 lbs. to 8 lbs. only reduces the velocity from 1690 to 1619 ft.

APPENDICES.

APPENDIX, No. I.

[1]

WAR OFFICE,
26th August, 1859.

SIR,

I am directed by Mr Secretary Herbert to transmit, for the information of the Ordnance Select Committee, a copy of a letter which has been addressed to Mr Britten on the subject of experiments with his projectiles and system of rifling. I am also to enclose the programme referred to, which I am to request may be followed, should the Committee see no objection.

I am Sir, &c.,
(Signed) K. BACON.

The Secretary,
Ordnance Select Committee,
Woolwich.

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[2]

WAR OFFICE,
26th August, 1859.

SIR,

I am directed by Mr Secretary Herbert to acknowledge the receipt of your letter of the 16th instant, and in reply to request that you will forward to Shoeburyness the ten shells which you have prepared for a preliminary trial, notifying to the Secretary to the Ordnance Select Committee at Woolwich that you have done so, and requesting that a day may be named for the experiment. The programme you have prepared has been forwarded to the Committee, with directions to adhere to it, should they see no objection.

I am further to state that Mr Herbert considers that fifty projectiles will be sufficient for the proposed competitive trials of different plans of rifling. I am therefore to request that you will proceed with their manufacture at a cost not exceeding £75 (seventy-five pounds), reporting to this office when they are ready for delivery.

I am to take this opportunity of enclosing a copy of the Report of practice made with twenty of your projectiles in May last, the request which was contained in a former letter from you was accidentally overlooked.

I am, Sir, &c.
(Signed) J. R. GODLEY.

Mr Bashley Britten,
Sydenham Hill, Kent, S.

P.S. I am to request that you will furnish at once an estimate of the probable cost of rifling the 32-pr. service gun, which you have undertaken to prepare for the experiment alluded to.

[3]

Programme proposed by Mr B. Britten.

The gun to be fired at 10 degrees elevation.

Allowance to be made for constant deflection caused by the rifling. The same amount for each round.

Range, deflection, and time of flight, and recoil of gun to be noted.

Charges of powder as follows :—

Round No. 1	5 lbs.	Round No. 6	6 lbs.
2	5 "	7	6 "
3	5½ "	8	6 "
4	5½ "	9	6 "
5	5½ "	10	6 "

Mr Britten to be present.

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[4]

Instructions to the Superintendent of Experiments, Shoeburyness.

ORDNANCE SELECT COMMITTEE,
8th November, 1859.

Programme of experimental practice to be carried on at Shoeburyness, with a 32-pr. iron gun, rifled as proposed by Mr Bashley Britten.

Fifty projectiles are provided; the accompanying Memorandum A, shows their weight and diameter.

To be fired as follows :—

(1) Ten rounds at such elevations, and with such charges as Mr Britten may deem desirable, with a view to ascertain the proper charge and correction of deflection.

(2) Twenty rounds at 5° elevation, with the charge Mr Britten may have determined upon, from result of the ten preliminary rounds. (This charge must not be altered).

(3) Twenty rounds at 16° elevation, with same charge as at 5°.

Note charge, elevation, recoil, time of flight, range, deflection, and facility in loading.

The men to be placed in security. Reports in duplicate to this office as usual.

The accompanying Memorandum B, shows the stores demanded for this experiment.

The Committee will be present at this experiment. Due notice will be given of the day appointed.

By order,
(Signed) J. A. CAMPBELL, Lieut.-Col. R.A.,
Acting Secretary.

The Superintendent and Commandant,
Shoeburyness.

[5]

MEMORANDUM,

8th November, 1859.

Stores demanded for experiments with a gun rifled by Mr Britten. (Requisition No. 875).

Ordnance—Iron 32-pr. rifled by Mr Britten	1
Carriage, Experimental, for ditto	1
Cartridges, flannel, empty, 32-pr., 6 lbs.	50
Powder, L. G. W. A. lbs.	300
Tubes, friction, copper	55

Supplied by Mr Britten.

Projectiles, compound elongated	50

APPENDIX, No. II.

Mr NASMYTH'S GUN.

REPORT OF THE SUPERINTENDENT ROYAL GUN FACTORIES, ON THE BURSTING OF 32-PR. No. 4475, AFTER ITS CONVERSION INTO A BREECH-LOADER ON Mr NASMYTH'S PLAN.

Royal Gun Factories,
27th September, 1859.

Sir,

The following is a Report of experimental practice with a 32-pr. service gun (converted into a breech-loader agreeably to Mr Nasmyth's plan), carried on at the proof butt, Plumstead Marshes, as per requisition of the Ordnance Select Committee, 15th September, 1859.

The gun selected for this experiment was made at the Lowmoor Works, and supplied by Mr Hood.

Nature, 32-pr...........	Register No. 4475 Foundry „ 8621
Weight	58 cwt. 3 qrs.
Length	9 feet 6 inches.
Calibre..................	6·375 inches.

Cast 26th April, 1859.

Proved 1st June, with the following charges, viz.—

Powder, 1 cartridge	$21\frac{1}{2}$ lbs.
Shot solid, weight	32 „
Wads, junk	2

After firing two rounds with the above charges, the gun was searched, water-proved, and declared serviceable.

Under the directions of Mr Nasmyth, this gun was fitted in the Royal Gun Factories Department with a screw breech plug, worked by a 5 ft. lever.

The plug is made of wrought-iron from best selected scrap; it is $12\frac{1}{4}$ inches in its entire length, $9\frac{1}{4}$ inches of which is screwed with a **V** thread, rounded at the top and bottom, which fits into a corresponding length prepared for it in the gun.

The angle of the side of the thread $=60°$. Pitch of the thread $=\frac{1}{8}$ inch.

The point of the plug is cylindrical (diameter 6·8 inches), terminating in a frustrum of a cone (slant height $\frac{3}{8}$ inch) which fits into a recess made for it in the bore of the gun.

Diameter of plug at the breech end $=8{\cdot}1$ inches.

Exterior diameter of thread next the chamber $=8$ inches.

The screw is therefore slightly tapering, which facilitates its insertion and removal.

A tapering hexagonal hole is slotted out of the breech plug, into which is inserted a corresponding solid pin of wrought-iron, terminating in a knob. Through this knob the lever is passed for working the screw.

Weight of screw, 133 lbs.

The gun was tested for endurance, as per programme received on the 15th instant. The following shows the results :—

19th September, 1859.

Fired ten rounds, loading through the breech, the screw piece thoroughly cleaned and oiled after each round. No indication of gas escaping was perceptible outside the screw, but the threads inside were discoloured by the gas to the extent of from 6 to 10 inches along its length.

The position of the screw was accurately determined before firing and immediately after, but not the slightest displacement was observed during the experiment, showing that the strength and pitch of the screw were well adapted for the purpose.

In firing the first five rounds, the screw was difficult to remove, owing, perhaps, to a slight compression of the threads; at the tenth round it became so firmly fixed that no mechanical appliance at hand could start it. The lever was bent at right angles by the force exerted. In this state the gun was left for some time.

20th September.

To remove the breech, experienced workmen were employed, and succeeded in doing so after four hours labour with sledge hammers, &c.

The apparent cause of the screw becoming fixed was a thick coating of solid residuum from the fired gunpowder, and on its being cleaned and oiled, worked easily in the succeeding ten rounds.

To test the effect of "fouling" on the screw, two rounds were fired without cleaning; the increased friction required an extra power of two men to overcome it, namely six men instead of four.

At the 14th round fissures appeared at the joint in the bottom of the bore, and gradually increased at every round.

In firing ten rounds this day with cylinders equal to two shot, no further indication of gas escaping was observed than that already detailed.

21st September.

Commenced firing with cylinders equal to three shots. Finding the black deposit on the screw-piece easily removed by water, this was used in the remainder of the experiment and oil discontinued.

The lever worked easily, and the time of loading reduced one-third, namely from fifteen to ten minutes.

The gun burst in the 7th round of this day's practice, or the 27th of the experiment.

Impressions of the vent and the bottom of the bore were taken after every 10th round, but no alteration in the condition of either was observable.

The general features of the fractured gun may here be stated.

Chase broken off close behind the trunnions; remainder of the gun split into three segments, parallel with the bore, the top line of separation through the vent.

Portions of the breech broken off at the 1st and 2nd threads.

The screw breech was found in rear very little damaged.

The fragments of the gun have been put together, and are now in the museum of the Royal Gun Factories for inspection, if required.

Table of Results.

Date.	Number of rounds.	Charge.			Cylinders recovered.		Pene-tration.	Mean recoil.	Remarks.
		Powder.	Shot or cylinders.	Wads.	Whole.	Broken.			
		lbs.					ft.	ft.	
19th Sept. 1859	10	10	1 32-pr. shot	1	6	4	8	$5\frac{1}{4}$	
20th " "	10	10	1 cylinder =64 lbs.	1	9	1	10	$9\frac{1}{2}$	
21st " "	7	10	1 cylinder =96 lbs.	1	4	3	10	$12\frac{1}{4}$	Burst this round.

I have, &c.

(Signed) J. W. Haultain, Capt.-Instructor, R.G.F.
For Superintendent.

The Secretary,
Ordnance Select Committee.

APPENDIX, No. III.

TABLE SHOWING THE RESULTS OF MECHANICAL TESTS APPLIED TO SAMPLES OF LOWMOOR CAST-IRON.

Minute.	Ordnance.		Mechanical test. lbs. per square in.		Specific gravity.	Remarks.
	Nature.	Foundry No.	Tensile.	Trans-verse.		
	13-in. mortar	6,903	29,270		7·251	
	„ „	6,938	29,571		7·235	
	„ „	6,958	29,726		7·234	
	„ „	6,959	29,307		7·232	Used on board the "Rocket" in the Baltic, 1855. Had lead run into a cavity at bottom of bore.
	„ „	6,344	29,231	7,425	7·170	
	„ „	7,047	29,947	7,865	7·223	
	„ „	6,438	28,628	6,910	7·250	
	68-pr. gun....................	7,366	29,766	11,448	7·253	
	„ „	7,369	30,662	11,478	7·194	
	„ „	7,370	28,703	11,883	7·211	
	12-pr. bore in 32-pr. block	1	26,454	7,773	7·217	Rifled on Mr Whitworth's principle. Burst at practice, at Shoeburyness.
	Means		29,206	9,254	7·225	
8043	32-pr. gun....................	11,000	29,421 26,218	29,000		Burst in proof. Min. 6207.
„	„	11,130	25,163 27,322	27,084		Tested to destruction. Min. 6554.
„	„	11,133	27,800 27,498	27,084		Burst in proof. Min. 6207.
7860	Mr Haddan's gun, 32-pr.	8,640	27,414 30,211	28,200 27,842		Tested to destruction. Min. 7071.
1450	6·5-in. hooped gun	9,258	29,096 31,673 30,285			„ „ Min. 1004.
„	7·0-in. hooped gun	9,420	28,963 27,104 30,508			„ „ Min. 1119.
„	7·5-in. hooped gun	9,363	28,246 28,515 29,366			„ „ Min. 1119.
5483	70-pr. cylinder hooped ...		30,813 30,128	29,500		„ „ Min. 5234.
„	32-pr. hooped gun		26,368 25,884	27,000		„ „ Min. 5234.
7869	70-pr. „	9,342	29,608 27,122	26,800		„ „ Min. 6350.
„	32-pr. „	428	27,443 25,615	26,400		„ „ Min. 7024.
7861	68-pr. unstrengthened gun	8,544	21,999 27,800	27,800		„ „ Min. 7450.
„	32-pr. „	8,541	30,060 29,083	27,900		„ „ Min. 6885.
5801	68-pr. hooped gun		29,382 29,683	29,000		„ „ Min. 5415.
			28,251	27,771		
			28,501	27,969		

APPENDIX, No. IV.

REPORT ON MR WHITWORTH'S SYSTEM OF RIFLING.

Committee Minute, No. 4388—$15\frac{7}{61}$.
Report, No. 1708.
Subject.—Mr Whitworth's system of muzzle-loading rifled cannon.

With reference to W. O. letter of 8th June 1861, $\frac{80}{\overline{W}}{445}$ requesting the Committee to report as soon as possible whether they consider Mr Whitworth's system of rifling as the best suited for muzzle-loading guns.

Committee's Report.

15th July, 1861.

1. In replying to Lord Herbert's question, whether the Committee considered Mr Whitworth's system as the best suited for rifling muzzle-loading guns, the Committee think it necessary to point out that they have as yet had little or no experience of this system with common or shrapnel shells, and but little experience of it in any way bearing on the present enquiry, for out of fifteen muzzle-loading rifled guns, which have been made on this system, seven are in brass blocks of field calibres, to which it is supposed that the question does not refer.

The following is a list of the muzzle-loading Whitworth guns:—

A.—Brass Guns.

	Rounds recorded.
A. 1.—5-pr. in 6-pr. block, 1858, 3-pr. calibre	40
A. 2.—9-pr. in 9-pr. block, 1858, 6-pr. calibre	218
A. 3.—9-pr. in 12-pr. block, 1857, 12-pr. calibre	37
A. 4.—32-pr. in 24-pr. howitzer block, 1856, 12-pr. calibre, shells 23, 36, 48 lbs.	18
A. 5.—12-pr. in 9-pr. block, 1861, 3-in. calibre	140
A. 6, 7, do., not yet tried by the Ordnance Select Committee	0
A. 8.—70-pr. in 95-cwt. block, 1861, not yet tried	0

B.—Cast-iron Guns.

B. 1.—32-pr. of 63 cwt.; calibre, $\frac{4{\cdot}5''}{4{\cdot}0''}$; weight of shot, $32\frac{1}{2}$ lbs.; charge, 6 to 9 lbs.; one turn in 6 ft. 8 in.; burst on the 11th May, 1858, at Shoeburyness, at the 7th round, with 9 lbs. charge, at 15° elevation.

B. 2.—32-pr. of 63 cwt.; calibre, $\frac{4{\cdot}5''}{4{\cdot}0''}$; weight of shot, 32 lbs.; one turn in 6 ft. 8 in.; burst at Shoeburyness on 3rd December, 1858, at the 14th round, with 5 lbs. charge, at 10° elevation.

B. 3.—68-pr. of 95 cwt.; calibre, $\frac{5{\cdot}5''}{5{\cdot}0''}$; shot, 68 lbs.; charge, 10 to 12 lbs.; one turn in 8 ft. 4 in.; burst at Portsmouth, 8th October, 1858, at the 8th round. The shot from this gun pierced a 4-in. plate of homogeneous

iron on H.M.S. "Alfred," at 420 yds., with 12 lbs. charge, penetrating also 9-in. oak backing.

C.—Wrought-iron or Homogeneous-iron Guns.

C. 1.—Experimental, No. 105. Homogeneous-iron hooped 70-pr. of 70 cwt.; $\frac{5{\cdot}5''}{5{\cdot}0''}$ calibre; shot, 70 lbs.; one turn in 8 ft. 4 in. A crack appeared after proof on the 22nd April, 1861, running along one of the angles for a length of 3 ft., and ran through the female screw of the breech plug, so as to permit water to be easily forced through. (See Report, No. 1630—$20\frac{5}{61}\frac{80}{\frac{W}{417}}$). The proof charge was 18 lbs.; the gun had fired—

2 rounds	5 lbs. charge.	1 rounds	12 lbs. charge.
2 "	7 " "	2 "	18 " "
3 "	9 " "	= 10 rounds.	

C. 2.—Experimental, No. 102. Fellow gun to the last, and subjected to the same proof, which it has passed without apparent injury; but the Committee have not yet been in a position to carry into effect Lord Herbert's instructions of the 25th March, 1861, $\frac{84}{\frac{W}{421}}$ with reference to an experimental trial of it.

C. 3.—Experimental, No. 106. Fellow gun to the two last, but described as of wrought-iron. To be reported upon by the Admiralty; but not yet ready for issue—$\frac{84}{\frac{W}{421}}$.

C. 4.—Experimental, No. 107.—Similar to the last; not yet delivered, and no instructions received by the Committee respecting its future trials.

2. In addition to the above, there is a class of breech-loading guns, which are expressly recommended as equally available as muzzle-loaders, and which may be considered in the latter capacity on the present occasion.

D. 1.—Experimental, No. 104. Breech-loading 80-pr.; $\frac{5{\cdot}5''}{5{\cdot}0''}$ calibre; weight, 81 cwt. 3 qrs.; one turn in 8 ft. 4 in.; homogeneous iron hooped.

This gun fired about 40 rounds at Southport, with charges of 12 and 14 lbs., previous to its purchase by the War Office.

After proof at Woolwich with 24 lbs. charge, on 22nd November, 1860, it was sent to Portsmouth, where, after twenty-one more rounds, a dangerous fracture was discovered on 31st January, 1861, in the inner cylinder, and it is not considered to be in a fit state to use; the Committee have requested permission to test it to destruction, but have been informed that Lord Herbert withholds his approval of this proposition until Mr Whitworth has had an opportunity of stating his views on the subject. Mr Whitworth requested that, before anything more was done, certain accurate gauges should be made, and these have only just been reported ready.

D. 2.—Experimental, No. 91 (1861). 12-pr. breech-loading gun, of $\frac{3{\cdot}00''}{2{\cdot}75''}$ calibre; weight, 9 cwt. 3 qrs.

This gun has fired 144 rounds of shot. Mr Whitworth has been authorized to supply shells, for which the Committee are waiting.

3. It will be seen from the foregoing statement, that the evidence before the Committee is unfavourable to the safety of Mr Whitworth's system, as applied to either cast-iron or homogeneous-iron guns of large size, and it will be evident from a consideration of the system itself, that it must throw an extraordinary strain on the gun.

4. The peculiarities of this system consist in—

(*a*) Polygonal rifling;

(*b*) Small calibre, or somewhat more elongated projectiles than usual;

(*c*) Very rapid twist;

(*d*) Extremely perfect finish, and mechanical nicety of fit in the projectile.

The Committee are not aware of any mechanical superiority of the polygonal system of rifling over other systems, supposing them all to be executed with equal precision. It has the disadvantage of presenting six lines of reduced strength along the whole length of the bore, against which a violent rending action is exerted by an unyielding projectile. The absence of windage in the guns first made, and the extreme precision of fit attained, rendered the operation of loading also a difficult one, the projectile being very apt to stick in the bore; this has been partially remedied in the guns of later manufacture, by an alteration in the form of grooving; the sides of the polygon are now no longer plane, but the precision of the gun appears still to depend very much upon closeness of fit, which the Committee consider that it would be difficult to maintain. Iron projectiles cannot be guarded entirely from rust; the bearing surfaces would require to be cleaned and painted from time to time. If originally planed and finished with the nicety hitherto applied to them, they would be liable to vary in diameter by the effect of rusting, scraping, and painting, so that some of them would probably not go home in the bore. If not so finished, but left with a moderately easy fit, calculated to allow for these contingencies, the gun forfeits one of its principal claims to superiority.

5. A small calibre, or preference for elongated projectiles, may be called another distinguishing feature of Mr Whitworth's rifled-cannon system, although in this respect the difference is not so great between his projectiles and the Armstrong projectiles, as it is between his rifle bullet and the Enfield bullet. His 12-pr. shot are 3·4 calibres in length, Sir Wm. Armstrong's being only 2·3 calibres long. The average of nine sorts of hollow shot and shells gives a length of 3 calibres, and some of them are as long as

4 calibres. No Armstrong common shell is 3 calibres long; their average length is 2·8 calibres. This construction generally gives a greater strain on the gun, by the increased length of column to be moved by the elastic force of the gas, and the reduced area of the base on which the gas acts.

It is not the best form for common or shrapnel shells, but is favourable to the penetrating powers of the shot, and Mr Whitworth has in consequence attained considerable success in one instance against a $4\frac{1}{2}$-inch iron plate, which was absolutely penetrated by a 68-pr. bolt of $\frac{5{\cdot}5''}{5{\cdot}0''}$ diameter, at 420 yards.

The Committee are not prepared to say that the superior penetrating power of the shot is an advantage for general service which would counterbalance any decided loss of relative efficiency, in the common shrapnel shells, should such be hereafter substantiated; but it is undoubtedly a property not to be lost sight of.

6. A rapid spiral is the proper accompaniment of a great length of projectile. It is not in itself an advantage, but the reverse, bringing a greater strain on the gun, and augmenting the chance of the shot sticking in loading; but it is conducive to accuracy, and is an important part of the system advocated by Mr Whitworth, although not peculiarly his own.*

7. Mechanical nicety of finish.—Mr Whitworth's European reputation as a machinist has naturally led to a successful endeavour on his part to attain a great degree of perfection of finish in his guns and projectiles, but the Committee believe that the Armstrong breech-loading guns and projectiles are equally highly finished; and as regards muzzle-loaders, the machinery now in the Royal Gun Factories (which originally owes much of its perfection to Mr Whitworth's mechanical discoveries) is capable of turning out guns of any system that may be adopted with equal nicety if required. This feature, therefore, if any stress is laid upon it by Mr Whitworth, furnishes no reason for preferring the polygonal system to any other for muzzle-loading rifled guns.

8. It remains to be stated whether the range and accuracy of the Whitworth system is superior to other muzzle-loading rifle systems. It will be seen that the Committee have had but little experience of guns assimilating to those which are required for garrison and naval service. Range and accuracy in rifled guns depend materially upon length; this is strikingly evidenced, as to range, by the difference between Mr Whitworth's muzzle-loading and breech-loading 12-prs.; the latter is $36\frac{1}{4}$ inches, or $12\frac{1}{3}$ calibres longer than the former, and with the same charge, has a range exceeding the other by 250 yds. at 2°, by about 270 yards at 5°, and by about 450 yds. at 10°. The corresponding deflections reduced to a mean line, and corresponding errors of range, are—

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* So far back as 1791, experiments were made at Woolwich by Lieut.-General Parker, with 8-grooved rifles of ·61 diameter, and 1 turn in 20 inches and 30 inches. The regulation rifle of the period had 1 turn in 120 inches. The ball was spherical.

Breech-loading.				Muzzle-loading.			
Elevation.	Range.	Difference of range.	Deflection.	Elevation.	Range.	Difference of range.	Deflection.
°	yds.	yds.	yds.	°	yds.	yds.	yds.
2	1289	29	·75	2	1031	18	·63
5	2471	95	·64	5	2200*	24*	2·16*
10	4400	26	2·92	10	3950	64†	6·90†

* Mean between 3° and 7°.

† Means for 9°. None fired at 5° or 10°, for which the ranges are interpolated.

Before, therefore, the Whitworth polygonal system can be accurately compared with other systems of rifling muzzle-loading guns, those systems should first be represented by guns of equal mechanical perfection, and both by guns of the same length, or at least of that length which is finally adopted for the corresponding guns of each system. Nevertheless the Committee feel warranted in expressing their impression that no muzzle-loading rifle gun they have tried has exceeded Mr Whitworth's in range and accuracy.

9. The foregoing statements show how far the Committee are from any grounds for giving an affirmative answer to the question, whether Mr Whitworth's system of rifling is the best for muzzle-loading guns. The qualities of range and accuracy appear as yet to be attained at the cost of extraordinary strain upon the gun, unfitting it for use with cast or even homogeneous iron; of a somewhat disadvantageous form of projectile for common and shrapnel shells; and of an expensive construction of gun; and the Committee are not prepared to say that they are worth all this. At all events, looking to the financial and other consequences of a false step, they think it impossible to recommend this system for adoption on the strength of their present experience of it.

(Signed) J. St GEORGE,

President.

APPENDIX, No. V.

REPORTS ON RIFLING CAST-IRON GUNS.

[1]

Committee Minute, No. 942—20$\frac{4}{60}$.
Report, No. 762.
Subject.—The enduring power of cast-iron hooped guns. The best plan of rifling such guns.

With reference to W.O. letter, 8th March, 1860, $\frac{\frac{73}{3}}{792}$ and 17th April, 1860, $\frac{\frac{57}{2}}{3670}$.

Committee's Report.

25th April, 1860.

1. The Ordnance Select Committee think it due to themselves to point out respectfully to the Secretary of State for War, that the delays which have arisen in the course of their inquiry into the best method of rifling the cast-iron muzzle-loading guns of the service, and of increasing their strength, if at present insufficient, have arisen from causes beyond their control; and that they have not failed in exertions to bring this very important question to some practical solution.

2. The Committee received notification from the War Office that each of the under-named gentlemen was to be allowed to rifle a service 32-pr. gun upon his own plan, but with a pecuniary allowance calculated to cover the expense, on the dates against their respective names; and they add the dates on which the guns so rifled were reported to them as ready for trial, and other particulars.

Name.	When notified to Committee.	Gun reported ready.	First trial made.
Mr B. Britten	August 26, 1859	October 19, 1859	November 16, 1859
Mr L. Thomas	„ 24, 1859	„ 1, 1859	„ 15, 1859
Mr J. C. Haddan	„ 19, 1859	March 16, 1860	Not yet made.
Mr Nasmyth	July 27, 1859	Withdrawn.	
Mr Lancaster	August 17, 1859	February 17, 1860	March 22, 1860
Mr Jeffery	December 27, 1859	„ 22, 1860	Trial waits completion of experiments with Mr Jeffery's other guns.
Mr Whitworth	August 24, 1859	Not yet reported.	

In the case of Mr Haddan* and Mr Lancaster†, the projectiles were not ready until some time after the gun. Some time is necessarily required,

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* Projectiles received, 12th April, 1860. Weighed and returned to Principal Military Storekeeper, 18th April, 1860. Sent to Shoeburyness, 24th April, 1860.

† Mr Lancaster's projectiles not yet reported ready.

after they are ready, to weigh and gauge them, return them for issue, and transmit them to Shoeburyness.

It will be seen that some of the modes of rifling selected by the Secretary of State for this competitive trial, have not been tried to this day. Nor is there one instance in which the advocate or inventor of a system has presented himself to the Committee with his gun and projectiles in a state of readiness for a direct and final trial; each gentleman, as yet, has required a number of preliminary experiments to furnish himself with data on which to base his final arrangements.

The Committee are far from imputing blame to them for this, it being next to impossible to determine many of the minor details, on which the success of each method depends, without such experiments; but it will be seen that as every step necessitates some delay and some correspondence, the progress of the Committee must be retarded thereby.

3. In addition to the foregoing competitive trials, Mr Haddan has been allowed to rifle a second 32-pr. gun, in a manner slightly different from the competitive gun, which is untried. Commander Scott, R.N., has been allowed to rifle a 32-pr. service gun on a method of his own, and at his own expense, the trial of which is incomplete; and there is a 68-pr. gun now being rifled on a plan by Mr Parrott, of New York; but this last is principally a trial of the metal or block.

4. The Committee do not suppose it to be the wish of the Secretary of State that a final conclusion should be arrived at so long as any of the systems ordered by him to be tried are untried; their present experience has led them to entertain a favourable opinion of the method of Mr Britten; and while they doubt whether unhooped guns, cast in iron of the quality hitherto used for gun founding, as such as the existing service smooth-bored guns are made of, can be employed with confidence for rifled guns, even in blocks of more than the service weight, they entertain a hope that Mr B. Britten's mode may be hereafter applied with advantage to service muzzle-loading guns strengthened with iron hoops, should no better method be brought to light.

The ranges obtained by this gentleman are as follows:—

(1) 15th Sept. 1859, with a rifled service 32-pr., of 56 cwt., charge, 6 lbs., projectile weighing 49 lbs., 10° of elevation, a mean range of 3595 yds.; being about 800 yds. more than the range of the same gun unrifled, at the same elevation, with 10 lbs. charge, and a projectile weighing only 32 lbs. The deflections were regular and the ranges uniform within satisfactory limits.

(2) With a rifled service 32-pr. of 58 cwt., projectile weighing 51 lbs., 10° of elevation, a mean range of 3236 yds.; being about 450 yards beyond the range of the same gun unrifled, with 10 lbs. Or with a charge reduced to 5 lbs., and a projectile weighing $49\frac{1}{2}$ lbs., a mean range of 3107 yds.; being about 300 yds. more than the same gun unrifled with 10 lbs. The necessity of greatly reducing the charge undoubtedly detracts from the apparent advantage of rifling cast-iron guns, as regards range; but there remains an actual and considerable gain, even in this respect; and when the greatly

increased accuracy and uniformity of the practice is considered, and the greater weight of the projectile thrown, the real gain by rifling will be seen to be very considerable.

Mr B. Britten's other guns are rifled in blocks of extra weight, and therefore need not be here alluded to, except to say, that the method of rifling and the system of projectiles has been so far successful in them also, as to warrant the preceding remark—"That it is a system which at present appears susceptible of practical application, although the Committee still hope a better may be found."

5. The Committee are inclined even to believe that Mr Britten's method will be found to strain the gun less than the shunting plan, understood to have been provisionally adopted by order of the Secretary of State.

6. Respecting this latter system, the experience of the Committee is at present limited to the following facts:—

(1) A shunt gun, unhooped, No. 8616, of 5·25″ calibre, burst at the 40th round, at Shoeburyness, 14th October, 1859.

(2) A shunt gun, hooped, No. 9185, of 6·50″ calibre, burst at the 4th round, on 6th February, 1860.

(3) A shunt gun, hooped, of 6·50″ calibre, No. 13, with extra ring, burst at the 12th round, on 18th April, 1860.

(4) A shunt gun, unhooped, No. 8639, of 6·5″ calibre, has fired 327 rounds, and is still serviceable.

(5) A shunt gun, unhooped, No. 8399, of 6·5″ calibre, has fired 43 rounds, and is still serviceable.

(6) A shunt gun, hooped, No. 8267, of 8·3″ calibre, is under preliminary trial, and had fired 31 rounds on 31st March.

(7) Five shunt guns, hooped, as under, have been assigned to the Committee for experiment, and three have been received, one of which has an extra cylinder.

It is proposed to test them to destruction, when the views of the inventor as to the best method of doing so have been ascertained.

Two of 6·5″ calibre.
Two of 6·5″ calibre, extra cylinder.
One of 7·0″ calibre.

It will be seen that these facts are neither of a character, nor in themselves sufficient, to warrant the Committee in recommending as yet the adoption of the shunt mode of rifling.

7. The Committee think it right also to call the attention of the Secretary of State to the fact, that there is as yet little proof that the method of hooping cast-iron cylinders, as actually employed in the Royal Gun Factories, is adequate to give them the necessary strength to stand being rifled. Out

of six rifled guns thus hooped, three have already burst, three more hooped guns, not rifled, have also been burst in the course of experiments to test their endurance, and one, at least, of them did not exhibit any remarkable endurance, viz. the 6·5-in. gun.

(8) 10-in. gun, No. 5071, burst at the 39th round, on 28th November, 1859, being the 9th with a cylinder equal to four solid round shot and 20 lbs. charge.

(9) 68-pr., No. 3973, burst at 51st round, being the 1st with a cylinder equal to six round shot; charge, 16 lbs.

These two guns were hooped in a manner somewhat different from the one now employed.

(10) A 6·5-in. gun, No. 13, 97¾ cwt., hooped, but not rifled, burst on 18th April, 1860, at the 36th round, with a cylinder equal to four round shot, and 16 lbs. charge.

8. It is very possible that improvements may be made upon the method of strengthening, or upon the preparation of the block for receiving the cylinders or hoops employed; but at present there appear to be difficulties which call for the utmost caution, looking to the almost incalculable consequences of the bursting of even a few guns on board ship or in garrison, with such effects as generally attend these occurrences.

The discouragement to the *morale* of Her Majesty's fleet or troops might almost equal that of a series of defeats.

9. The Committee think it probable that service 32-prs., of 56 cwt., 58 cwt., or 64 cwt., the calibres of which are a little less than 6·5″, if turned down externally to cylinders behind the trunnions, and then strengthened with hoops, would be found stronger than guns cast to the requisite dimensions and hooped, as is now the practice; and they request that one gun of each of these natures may be thus prepared and tested to destruction, in comparison with the ordinary hooped guns now about to be tested. The estimate for this service is £525.

10. The Committee also recommend that a standard gun of 6·5″ bore be cast and rifled in gun metal (brass), and subjected to experiment to ascertain the power of this metal to resist the action of the shot.

The first cost of such a gun will be £712; but the value of the metal, when returned for re-melting, will be about £350; making the actual expense of the gun about £462. Such a gun, being free from danger of bursting, will be of frequent use, and the ranges given by it will be available for forming Tables of Practice for the iron guns, if they are generally introduced.

11. With reference to the concluding part of the W. O. Memorandum of $17\frac{4}{60}$, the Committee will gladly avail themselves of the offer of the Secretary of State to give them the services of one or more Artillery Officers, to assist in bringing these present inquiries into the best form of muzzle-loading

rifled guns to a conclusion, and will submit the names of Officers whom they consider likely to render valuable assistance when they are prepared for them; but at the present stage of the inquiry they do not feel that they could be materially aided by such services.

(Signed) J. St GEORGE,
President.

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[2]

Committee Minute, No. 1632—13 7/60.
Report, No. 956.
Subject—Mr B. Britten's mode of rifling guns.
With reference to Sections 4 and 5 of Committee's Report, No. 762; dated 25th April, 1860.

Committee's Report.

19th July, 1860.

1. The Committee felt justified in expressing a favourable opinion of Mr B. Britten's system of rifling service guns in their Report No. 762; and although the competitive guns of Messrs Jeffery and Lancaster are untried, while that of Mr Haddan is still under trial, they consider that a further step may be prudently taken with Mr Britten's, to gain time; and in the possibility, if not probability, that this system, or a modification of it, may come into use.

2. With this view they request permission to test the endurance of the three rifled service guns, viz.—

A.	32-pr. of 56 cwt., has fired	77 rounds.
No. 1.	32-pr. of 58 „ „	228 „
No. 4.	68-pr. of 95 „ „	130 „

by continuing the practice with each until it has fired 300 rounds (the smallest number they consider capable of furnishing presumptive proof of a serviceable degree of strength). The number of rounds each has fired is marked above. Mr Britten has furnished an estimate of the expense of re-coating ninety-seven 8-in. shells, now in hand, and making up the number of the others, which amount is £359. 5*s*. The ammunition, and other stores requisite, will amount to £90. 12*s*. Total, £449. 17*s*.

3. The Committee, however, do not consider that the three guns, whether they succeed or not in standing that number of rounds, can be safely taken as a criterion of the rest of the guns in store, and request permission to take two more 32-prs. of 58 cwt., and two more 68-prs. of 95 cwt., indiscriminately from store, or from the first deliveries, one to be of Hood's, and the other of Walker's manufacture, to have them rifled in the same way, and to test them to destruction. The expense of this will be as follows:—

	£	s.	d.
Value of guns	333	7	0
Expense of rifling	79	0	0
Estimated expense of ammunition and stores, 30 rounds per gun	26	12	6¾
Estimated expense of elongated projectiles to be supplied by Mr Britten	175	0	0
Total	£613	19	6¾

Considerable as these estimates may appear, the Committee are persuaded that the importance of every possible precaution before introducing rifled cast-iron guns, is such, that the experiments cannot be dispensed with; and that it is only by these or similar steps, that the question can be advanced to a practical solution.

Should there be no Walker's guns on hand, or in delivery, the Committee suggest that they may be supplied by boring up one 32-pr. and one 18-pr. of the experimental guns of those calibres, bored in 68-pr. and 32-pr. blocks respectively, which are now in the Royal Arsenal, and are understood to have been intended for some departmental experiment on the shunt mode of rifling in 1858 or 1859.

(Signed) J. St GEORGE,
President.

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[3]

Committee Minute, No. 3927—$8\frac{5}{61}$.
Report, No. 1640.
Subject—Rifled cast-iron service guns.

With reference to W. O. letter of 26th March, 1861, $\frac{79}{\frac{B}{304}}$.

Committee's Report.

3rd June, 1861.

The Committee have given full and anxious consideration to the question referred to them by Lord Herbert, viz. to what service they would recommend the application of Mr B. Britten's rifled 32-pr. guns, designated No. 1 and A, in case they should stand the 1000 rounds, for which sanction was given in the letter from the War Office, dated 7th December, 1860, $\frac{79}{\frac{B}{304}}$. Of these rounds, only 300 have, at present, been fired by each gun, although shells have been delivered for firing 250 rounds more (500 shells).

As it is taken for granted that a cast-iron rifled gun, which has fired 1000 rounds, could not be issued for service, the Committee suppose the question put to them to be—"For what services do they recommend the issue of cast-iron rifled guns, supposing the particular guns in question to have given this proof of endurance."

2. In answering this question, the Committee assume that the intrinsic superiority of wrought-iron guns, as manufactured by Sir William Armstrong, over cast-iron guns, is a fact which will be universally admitted.

The almost immeasurable superiority of the former over the latter in point of strength and endurance has been placed beyond dispute; and, although more liable perhaps to total destruction by the effect of a blow from an enemy's shot, this is a contingency of small practical moment; the general effect of any direct blow being to make a cast-iron gun also unserviceable, as is fully evinced by 56 cast-iron guns disabled in the siege of Sebastopol.

The question then appears to turn chiefly on first cost, and facility of supply.

3. With regard to cost. A smooth-bored 32-pr. gun of cast-iron costs, by contract, about £58, rifling will add less than £1 to this amount. An Armstrong 40-pr., which may be treated as the rifled equivalent of the 32-pr., costs at present £360. The difference is indeed considerable; but it must be remembered that the 40-pr. is believed to be practically indestructible by mere use; at all events, these guns will probably stand many thousand rounds.

The duration of a cast-iron gun, even in a smooth-bored state, is much more limited; and these guns, when rifled, and firing elongated projectiles, will be exposed to a strain which will make it prudent, until their strength is well established, to restrict their employment to what may be considered a safe and moderate limit, however much the charge may be reduced; consequently, a wrought-iron gun may be expected to outlast several of them, and thus, in fact, diminish the relative cost; although it must apparently still be against wrought-iron.

4. But a consideration of equal, or possibly greater importance, is the facility of supply. Cast-iron guns exist in vast numbers, and many of them are doubtless as fit for rifling as if they were newly cast for the purpose. They could be procured from the usual contractors in numbers with great rapidity, and at a small advance, on what they now cost in a smooth-bored state. The question is—"Does so urgent a demand exist for heavy rifled guns as to make it expedient to draw upon this source, instead of waiting until wrought-iron guns can take their place?"

The reply must turn principally on considerations which are beyond the cognizance of the Committee.

The Committee have no knowledge of the powers of manufacture of either Woolwich or Elswick, the probable requirements of the navy, the probable requirements of fortresses and coast defences, or the sum of money which is likely to be at the disposal of the War Minister annually for their production; consequently, they can only submit an opinion upon this point with great deference.

That opinion, however, is, that it is not *at present* worth while to rifle cast-iron guns *on a large scale*, for the following reasons.

5. It is understood that the Admiralty do not as yet intend to introduce rifled guns into ships of war in a larger proportion than 1 to 9 smooth-bored guns. If so, 500 or 600 will meet the naval demand, exclusive of the necessary reserve.

It is supposed that, taking fortresses and coast defences all round, the total proportion of rifled guns required for them at present will not be much larger than this; because, while there are many smaller works which, from their position and importance, may require to be armed with a larger number, there must be many extended positions, like Portsmouth or Plymouth at home, or like Gibraltar and Malta abroad, where the total number of guns mounted is so large that one-tenth rifled would probably be in excess of the place for this special arm; and others, for which a smooth-bored armament may suffice altogether, until the use of rifled guns by Foreign Powers is much more general than it now is.

On the whole, the Committee feel warranted in assuming that if there are altogether twelve or fourteen hundred heavy rifled guns in due proportion of 40-prs., 70-prs., and 100-prs., available in the course of three or four years, the immediate requirements of the two services will be satisfied, and that the country may safely leave its further wants to the ordinary course of supply. It appears that, up to the present date, only sixty-six 100-prs. and one hundred and thirty-nine 40-prs. are issued, or ready for issue; but the Committee are informed that, by the 31st March, 1862, there will be four hundred and eighty-seven 100-prs., and five hundred 40-prs., if present orders are carried out. This will come near to make good the whole immediate demand; and one or two years at the same rate of production will complete the supply, more especially if, as the Committee are informed, three hundred muzzle-loading wrought-iron 100-pr. guns are to be made in the current year, in addition to the four hundred and eighty-seven breech-loaders.

If these premises are granted, it would not appear worth while to introduce a new species of rifled ordnance requiring special projectiles, to serve so temporary a purpose as the supply *ad interim*.

6. It is believed that, when Lord Herbert, in the month of August, 1859, called upon a number of gentlemen in civil life—engineers and others—to endeavour to find the means of converting the service cast-iron guns into rifled guns, they all believed and represented themselves capable of doing this, on their several systems, in an effective manner without delay; and the question referred to the Committee was simply to decide which of the systems was the best.

In their Report, No. 762, of 25th April, 1860, the Committee entered into some explanation of the delay experienced in bringing the competition of these guns to a close. A year has since elapsed, during which the inquiry has been advanced by the completion of 300 rounds by two of the systems, but it is not yet finished.

The Committee thought it right to wind up the comparative trials by a match of all the guns against one another under similar conditions.

A demand was made for the necessary projectiles on the 8th February, 1861, and they have not yet been furnished, chiefly, as it is believed, owing to the desire of some of the competitors to make further alterations and improvements of detail in them.

Guided by this experience, and by that of the Armstrong equipment, the Committee do not suppose that when choice of a system has been made, the guns and projectiles will be available for issue for many months, reducing the period for which they might have value as a temporary *expedient* to narrow limits.

7. On the other hand, the Committee are aware, that the difficulties of dealing with wrought-iron in large masses are not yet entirely overcome; that muzzle-loading rifled guns, such as the service guns will be, if rifled, are likely to be preferred in some situations to breech-loaders; and that economy and facility of supply, if combined with a good degree of efficiency, must constitute advantages not to be lightly overlooked.

On these grounds, however great the absolute superiority of wrought-iron, when perfect, over cast-iron, they consider that the hope of at least being

able to rifle the latter, should it become necessary, had better not be abandoned.

They consider more especially that the time and labour devoted by each of the competitors to the perfecting of his own system requires that a decision should be come to as to their relative merits, and also that the present opportunity should be taken for setting at rest the question whether the material itself is capable of standing the strain put upon it when heavy projectiles are fired.

The only way to satisfy these ends is to conclude the competitive trial, and afterwards to fire all the guns with their proper service charge and projectile until they burst. If so many as seven 32-prs., rifled on different systems, all exhibit a satisfactory degree of endurance, by standing 1000 or more rounds, no hesitation need be felt in rifling cast-iron guns, should the demand increase beyond the power of supply in wrought-iron. Should even a few of them do so, and their strength be referable to any special principles of construction or system of projectile, a definite result will have been obtained by the whole enquiry; but to stop it at this moment will be to throw away all that has been done, and to leave grounds for re-opening the question at a future day.

8. The Committee then request authority to conclude the trial of endurance of Mr Britten's guns, towards which 500 rounds have already been supplied, and after the conclusion of the competitive trial, for which they are now waiting, to extend the same trial to all of the others, for the express purpose of ascertaining more conclusively than has yet been done, what cast-iron guns, rifled, will stand, when firing their proper service projectiles with service charges, as rifled guns, and also, whether systems which involve lead coatings, have a superiority in respect to endurance, which at all corresponds to the extra cost of the projectile.

Supposing the average endurance to be 1000 rounds, and the projectiles to be made in the Royal Laboratory, the expense will be about £3500 for stores, and added to the expenditure already incurred, or authorized in connexion with these guns, viz. £2820, the Government will have paid about £6320 for the result, exclusive of any premium or reward it may be thought right to give to one or more of the competitors.

Looking to the importance of the question both in a military and a financial point of view, the Committee do not think this an extravagant outlay. It is almost all in powder and shot. Under no circumstance could moral assurance of the prudence and safety of a change of material of this character be attained without long and costly preliminary trials, involving, perhaps, as extensive an expenditure of ammunition.

(Signed) J. St. GEORGE,

President.

[4]

Committee Minute, No. 7612—20$\frac{10}{62}$.
Report, No. 2518.
Subject.—The Lancaster oval-bored system of rifling as applicable to brass 9-pr. smooth-bored guns.
With reference to W.O. letter of 30th January, 1862, $\frac{80}{\frac{L}{174}}$, and former Report, No. 2044, of 23rd December, 1861.

Committee's Report. 24th Oct. 1862.

The Committee have to report that the trial of a single oval-bored brass 9-pr. to the extent of 200 rounds, against a service-gun of the same calibre, took place in June last; and they have lately been enabled to complete their Report on the subject by receiving the Report of the Inspector of Artillery on the state of the guns, which is as follows:—

Smooth-bored 9-pr., No. 853; Eardley-Wilmot, maker, 1859; weight, 13 cwt. 1 qr. 25 lbs.; after firing 200 rounds—

"Bore smooth, but slightly grazed by shot, and dented at 58 inches from muzzle; dent ·025 inch deep; vent true."

Oval-bored 9-pr., No. 839; Eardley-Wilmot, maker, 1859; rifled 1862; weight, 13 cwt. 1 qr.; after firing 200 rounds service 9-pr. round shot—

"Bore smooth, but grazed by shot; the graze being along the minor-axis, and produced by the bearing of the shot. There is also a dent at 10 inches from the bottom of the bore, or rather in front of the seat of the shot, caused apparently by the shot when taking up the rifling. Vent true."

2. It appears from the above that there is a slight but perceptible wear produced on the oval-bored brass gun in 200 rounds. This effect would doubtless have been greater, from their longer bearing and greater weight, if elongated shells of 15 lbs. had been fired, and indicates a limited durability in guns of this description, as compared with wrought-iron guns.

3. In respect to precision as a rifled gun, the Committee showed in their last Report, No. 2044, that the oval-bored 16-pr. (9-pr. calibre) was inferior in this respect to both the Armstrong and Whitworth guns: the present comparison has had reference only to its suitability for firing round shot. It will be seen by the accompanying abstract that inaccurate as is the smooth-bored 9-pr., compared with a rifled gun, it is far more accurate than the same gun firing spherical shot when oval-bored.

Comparing the results up to 1000 yds. range, at which distance alone would the round shot have any considerable advantage in point of velocity, the means are:—

Nature.	Mean of 4 ranges.	Mean of 4 differences of range.		Mean of 4 reduced deflection.
		yds.	In terms of range.	
	yds.			
Oval bore, firing round shot ...	583·5	66·9	·113	3·05
Smooth bore, firing round shot.	614·7	38·8	·063	1·95

The round shot from the oval bore on 78 rounds has a mean range 31·2 yds. less than that of the smooth bore, and a mean irregularity of range 28·1 yds. greater; or, referred to terms of the whole range, as 113 to 63. The mean deflection (each being referred to the mean direction of all the shots) is one-third greater. These results show that any advantage gained by the relatively high velocity of round shot from these oval-bored guns, as against elongated solid shot, would be more than made up for by their very inferior precision.

4. The Committee stated in their former Report general reasons which, in their opinion, made it inexpedient to adopt Mr Lancaster's proposition. They are confirmed in the conclusion by the present result, and do not recommend any further experiment.

(Signed) J. St GEORGE,

President.

APPENDIX, No. VI.

ARRANGEMENTS FOR THE CONCLUDING GENERAL TRIAL OF THE COMPETITIVE 32-PR. CAST-IRON SERVICE RIFLED GUNS.

August and September, 1861.

1st. The guns will be mounted in the order :—

No. 8658........	Britten.	No. 9050........	Lancaster.
8460........	Jeffery.	6842........	Shunt.
9127........	Scott.	9130........	French.
8640........	Haddan.	7138........	Service smooth-bore.

2nd. All will be laid at one object, namely, a cross piece or target.

At 1000	yds. for	2°.
2000	„	5°.
3000	„	10°.

3rd. The range serjeants, under direction of an officer, will ride in after every round, with a peg lettered :—

	B.,	J.,	S.,	H.,	&c., and
Numbered	1,	2,	3,	4,	&c.

and instantly mark the graze. Refer it carefully to mean line of range, and and plot down its place accordingly on ruled paper.

In the subsequent comparison, each shot will be referred to its own mean line, and all the deflections reduced to 1000, 2000, and 3000 yds., as the case may be.

4th. To prevent any mistake, a Redl's cone signal to be made, of the gun fired, by number.

5th. All elevations will be absolute, i.e. above the horizon, and be given by the same quadrant, with the utmost care—as to its position in the bore of the gun, and by the same officer.

The Committee will request the several inventors, if present, to leave the entire management in their hands, and to abstain from all interference in the service of the guns.

6th. The guns all to be fired with the usual precautions against accident. The spectators and detachments to retire before each round.

7th. All the shells will be fired plugged, but with full bursting charges in them.

8th. Fifteen rounds will be fired from each gun at 2° elevation, with the inventor's proposed service charge.

9th. The same will be repeated at 5°.

10th. The same will be repeated with 12 rounds at 10°.

11th. Five rounds will be fired at 2°; five at 5°; and five at 10°, with charges of $\frac{1}{10}$th the actual weight of the filled projectiles.

12th. There are some rounds to spare, in the event of its being decided to ascertain the initial velocity of each projectile with Navez's electro-ballistic-apparatus, which will partly depend on the condition of the guns at the conclusion of the present trial.

13th. The following Table contains the principal particulars of the projectiles to be employed in each system.

Competitive Rifled 32-pr. Guns.

	English Systems.	French Rifling.
Calibre	6·375 inches	6·48 inches.
Weight	53 cwt.	58 cwt.
Length	9 feet 6 inches	9 feet 6 inches.
Length of bore	9 feet ·6 inches	8 feet 9 inches.

Names of competitors.	Rifling.		Service charge proposed by inventor.		Shells.—Mean weight of 15 rounds.							Special charge $\frac{1}{10}$th.
	Grooves.	Twist.			Weight plugged.			Diam.	Length.	Capacity powder.		
		ft.	lbs.	oz.	lbs.	oz.	drs.	in.	in.	lbs.	oz.	lbs.
Britten	5	$\frac{1}{45}$	5	0	46	14	15	6·24	11·28	3	7	5·037
Jeffery	7	$\frac{1}{34}$	5	8	45	7	0	6·26	9·68	2	8	4·793
Scott	3	$\frac{1}{48}$	6	2	38	12	14	6·27	11·91	4	13	4·361
Haddan	3	$\frac{1}{25}$	7	0	51	1	6	6·19	12·02	3	6	5·446
Lancaster	Oval	$\frac{1}{30}$	6	0	46	5	8	{6·88 / 6·32}	12·04	4	7	5·078
Shunt	3	$\frac{1}{25}$	5	8	50	8	10	6·32	15·08	5	13	5·635
French	3	From 0 to 4·6519 in 38·548″	5	8	59	6	0	6·36	14·04	5	5	6·468
Service	Smooth bore		10	0	32	0	0*	6·177				

* Solid Shot.

J. H. LEFROY, Bt.-Col., R.A.,

Secretary, Ordnance Select Committee.

REPORT

ON

BARON LENK'S GUN COTTON,

BY PROFESSORS DR REDTENBACHER, DR SCHRÖTTER, AND DR SCHNEIDER.

TO

His Excellency Field-Marshal Johann Freiherr Kempen von Fichtenstamm,

President of the Royal Imperial Commission on Gun Cotton, June, 1863.

This Report—printed by the British Association, at their Annual Meeting, Newcastle-on-Tyne, 1863—is reprinted for the information of Members of the R.A. Institution. To which are added some comments, kindly furnished by F. A. Abel, Esq., F.R.S., Chemist to the War Department.

[NOTE.—The interesting Report of Professors Redtenbacher, Schrötter, and Schneider contains some statements and theoretical considerations which, if submitted to the members of the R.A. Institution without comment, might pass for fully established facts and generally adopted opinions, instead of being accepted only as views of the authors which are open to discussion, and, to confirmation or disproval by the results of experimental research. A few observations, in the form of notes, have therefore been appended to some parts of the Report, which appear especially to challenge criticism.—F. A. A.]

[COMMUNICATED BY THE SECRETARY, R.A.I.]

IN accordance with Your Excellency's wish, the undersigned submit the following opinion relative to the objections urged against the adoption of gun cotton for war purposes.

Introduction.

It is not possible within the limits of the present Report to discuss all the various products which, since the discovery by Schönbein, in 1846, of a method of chemical treatment whereby cotton might be rendered explosive, have been brought forward, examined, and applied, under the various names of "Gun Cotton," "Pyroxylin," "Fulmi-coton," "Nitro cellulose," &c.,—or, at any rate, to do more than mention such as have been brought under our notice in the course of experiments performed by us with Baron Lenk's gun cotton.

*** It should be stated that the full Official Report, from which the preceding paper is taken, contained many additional Tables of Practice of the several Guns under competition, also extra Plates in further illustration of the Report. The Committee did not think it necessary to reproduce these Plates and Tables of Practice.—E. J. B.

It is true that gun cotton has frequently and by various persons been manufactured by modifications of one of the two following processes, viz.:—

(1) By acting on cotton with mixtures of nitric and sulphuric acid.

(2) By acting on cotton with mixtures of saltpetre and sulphuric acid.

These two general processes have been so much varied in detail by different experiments, that the resulting specimens of gun cotton must necessarily have been most diverse in quality. The variations of detail may be classified as follows, viz :—

(1) Variations as to strength of acids.

(2) Variations as to the conditions of mingling the acids.

(3) Variations as to duration of chemical action.

(4) Variations as to temperature.

(5) Variations as to the removal of free acid from the resulting gun cotton.

These variable conditions being taken into consideration, it is no longer a matter of surprise that even the chemical composition of gun cotton has been differently stated by different authorities. Accordingly, whilst one set of chemists, in explaining the *rationale* of action whereby ordinary cotton is changed into gun cotton, refer the change to a substitution of one equivalent of hyponitric acid for three equivalents of hydrogen in the original cotton, another set affirm that four equivalents represent the hydrogen exchanged; and yet other chemists, five equivalents. In addition to these three definite compounds, various analyses have testified to an infinity of secondary bodies, the result of mechanical mixtures.

Unforeseen explosions of gun cotton occurring without any known cause, and assumed to have been the result either of spontaneous combustion, or of some unimportant elevation of temperature, as up to 50° or 60° C., have frequently been chronicled in the short history of this substance; whilst, on the other hand, reliable authorities have fixed the exploding temperature between 130° and 160° C.—another proof as to the variety of materials operated upon on a small scale. The chief experiments relative to gun cotton have been made by chemists upon small portions, one pound being looked upon as a considerable quantity. Results based on such data may be considered on a par with general conclusions as to the properties of gunpowder founded upon experiments with a mixture by hand of charcoal, sulphur, and nitre, in quantities yielding a pound weight aggregate.

Chemical changes involved in the manufacture of Gun Cotton.

2. The fact should be borne in mind, that the changes which cotton undergoes in its treatment with nitric and sulphuric acids conjointly, are not alone peculiar to cotton and other vegetable fibre, but that a great number of organic bodies are amenable to a corresponding change if they be similarly treated. The exact grade of mutation which any particular

organic substance may undergo when treated as above will differ, however, according to circumstances. Even if, as a rule, we assume that for every equivalent of water displaced, an equivalent of nitric acid is appropriated—or, what amounts to the same thing, if the assumption be that every single equivalent of hyponitric acid exchanges with a corresponding equivalent of hydrogen—still, variations of result may be accounted for by reference to the modifying conditions already indicated. However, the general deduction may be arrived at, that the amount of hyponitric acid appropriated is directly as the amount of hydrogen lost.

Possibly, the results obtained by chemists on the small scale, using small amounts of cotton and relatively large amounts of acid, may not be identical in composition with corresponding results of large-scale operations; time in both cases being constant. It may also be fairly assumed that certain portions of the original cotton may escape nitrification, wholly or partially. These suggestions tend to show the little value that can justly be attached to past experience with gun cotton, if cited in reference to the specific gun cotton of Baron Lenk.

Experiments by the French.

3 An extensive series of experiments with gun cotton must, however, not be passed over; the material having been produced commercially on a large scale, and the investigation moreover conducted by military and scientific authorities. A record of these experiments may be seen in Berthier's "Mémoire de l'Artillerie;" Paris, Bathelier, 1852.

Immediately after the discovery of gun cotton in 1846, the French Minister appointed a Commission of inquiry relative to it.

For a period of six years this Commission prosecuted its investigations, and the results are printed in the pamphlet above-mentioned.

These experiments were conducted on a large scale; five tons of gun cotton being manufactured. This Commission instituted the most searching inquiries relative to every possible ballistic and other military use to which gun cotton could be applied. No less than thirty tabulated digests resulted from the labours of this French Committee.

Experiments so seemingly exhaustive might reasonably prompt the assumption that no point relative to gun cotton and its application had remained undetermined. It might seem that the subject of gun cotton was definitively set aside after the decisive verdict which the following quotation records:—

"Dans l'état actuel, il n'y a pas lieu de continuer les expériences au point de vue de leur emploi dans les armes de guerre."

Perusal of the Report leaves no doubt either as to the pertinence of questions raised, or the intelligence manifested in the corresponding replies.

The French neglected to ascertain the true composition of the Cotton.

4. One point, however, was lost sight of by the French Commission, namely, the precise composition of the gun cotton operated upon. On this point the Commissioners are silent: hence the question, *whether one and the same chemical compound formed the subject of every experiment in the*

series, was never raised. The Report throughout is based on the assumption that identical methods of treatment must yield identical results; that no analysis was required: that practice in firing supplied the *ultima ratio;* and, lastly, that the results of explosion were referable to chemical composition wholly and absolutely. The first proposition is usually, but not *invariably* true, as every chemist knows.

Minor circumstances frequently influence the result of chemical energy, though primary conditions remain unchanged. Chemists sometimes, heeding these primary conditions only, imagine they have continued to do the same thing and to achieve the same result; whereas different acts have been performed, and different results accomplished. This has happened in prosecuting the manufacture of gun cotton, up to the experiments of Baron Lenk. What *may* take place during the change of ordinary cotton into gun cotton, under different conditions, can be thus expressed. The cellulose (matter of cotton) may yield up successive increments of hydrogen, to be replaced by hyponitric acid, according as the acid bath employed varies as to relative bulk, and the time of action varies. One equivalent of hydrogen is removable more easily than two, two than three, &c. &c.

In this way, not only may specimens of gun cotton (as commonly prepared) be made up of variable mechanical mixtures, of every chemical result possible under the circumstances, but the series may be still further extended by the interpolation of material upon which no chemical action has been exerted. Hence may be deduced a most important distinction between the French gun cotton and that of Baron Lenk.

Difference between the French Gun Cotton and Baron Lenk's.

5. According to the method pursued by the French Commission, the raw cotton was immersed in the acid mixture for one hour.

Baron Lenk leaves his cotton forty-eight hours in the acid bath.

The French cotton was afterwards dipped in running water for an hour or an hour and a half.

Baron Lenk's gun cotton lies four, six, or eight weeks in a stream.

The French cotton had, after washing, so much free acid left, that wood-ash ley (a solution of carbonate of potash, therefore), was neutralized by contact with it, and after long use became sour.

Baron Lenk's cotton is so freed from acid by long immersion, that a two per cent. solution of potash, in which two hundredweight of gun cotton had been boiled, had lost none of its alkaline properties; that is to say, that the cotton was completely free from acids, as experiments wholly accordant with those of the Imperial (Austrian) Engineers' Committee fully demonstrated. The French gun cotton having been prepared in a manner so different, it must necessarily have had a different composition to that of Baron Lenk's; hence it is clear that the French experimental results cannot, without considerable reserve, be accepted as precedents.

Lenk's Cotton is Tri-nitro Cellulose and uniformly composed.

6. It manifested no inconsiderable amount of confidence on the part of Baron Lenk, when the French experiments were known to him, that he did

not give up the gun cotton altogether; and he can only have been supported by the conviction based upon a thoroughly-grounded study of the entire process.

Baron Lenk calls the Hirtenberg cotton (and with full right) his cotton, as he prepares it by one constant, definite, and unvarying process.

Baron Lenk takes the strongest preparation of acid, one part nitric acid to three parts sulphuric acid; he impregnates a spun thread of cotton in a boiling solution of potash thoroughly, and leaves the acids to act cold upon the cotton during forty-eight hours.

These details of manufacture are all important; and the resulting cotton is also most convenient for the subsequent process of freeing from acid, drying, and working up; whilst during the time employed, the three most easily removed hydrogen equivalents of the cellulose are completely replaced by hyponitric acid, and during this time the action takes place through the body of the cotton uniformly, so that no isolated portions are less azotized than others; nor, if properly conducted, is any portion too highly azotized; in fact, it can be demonstrated that the Austrian gun cotton contains three easily removed equivalents of hydrogen.

Analysis.

7. *Analysis.*—This is demonstrated by the recorded analysis of the Austrian Imperial Engineers' Committee, 1861 (Vol. I. Part I, p. 21), wherein it is shown that Lenk gun cotton is almost wholly composed of tri-nitro cellulose.

ANALYSIS OF AUSTRIAN GUN COTTON.

Laboratory of Engineers' Committee, 1861.

In 100 parts.........	Tri-nitro Cellulose calculated.	No. 4.	Original Cotton.
Carbon	24·3	25·1	
Hydrogen...........	2·3	3·0	

University Laboratory, 1863.

No. 3. 1856.		No. 6. 1860.		No. 14. 1862.			Di-nitro Cellulose.
1	2	1	2	1	2	3	
24·4	24·5	24·6	24·2	23·6	23·9	24·1	28·6
2·7	2·8	2·6	2·7	2·6	2·4	2·4	3·2

If this analysis differs somewhat from the theoretical formula of the tri-nitro cellulose, the circumstance must be remembered that cotton is not pure cellulose, but that it consists of long extended vegetable cellules, in which there is always a little albuminous substance containing over 50 per cent. carbon, and 7 per cent. hydrogen, the presence of which even in such quantities easily increases the per centage of carbon and hydrogen.

The treatment with soluble glass has no influence on Baron Lenk's gun cotton, it being previously free from acids.

[The experiments made in this country confirm the conclusions arrived at by the Reporters, that there is no ground for the great importance attached by General Lenk to the treatment of gun cotton with soluble glass, adopted by him].

Gun cotton is always put into comparison as an explosive compound with gunpowder; but it must be remembered that one of the component parts of gunpowder—charcoal—is most irregular in quality, especially where the primitive method of preparing it is followed. Still, in theoretical disquisitions upon gunpowder, charcoal is taken into account as pure carbon.

Bunsen has so treated the charcoal in his experiments with Berne powder and Austrian army powder at the University Laboratory.

	Berne.	Austrian.	Powder.
Carbon…………	68·84	81·2	82·9
Hydrogen ……	3·67	2·8	2·99
Oxygen ………	27·49	13·6	12·1
Ashes …………	—	2·4	2

It is, however, well known that the Austrian charcoal is manufactered at a higher temperature.

The French chemist Violette, who effected the latest improvements of charcoal manufacture, proved a difference in charcoal of eight per cent. in hydrogen, and one per cent. ashes; and the comparative proportions of the charcoal of the same wood made at various temperatures varied from 340° to 800° C.

If it be considered that with us the manufacture of gunpowder as well as of charcoal is in the hands of ignorant workmen of the lowest class, who make at one operation and of the same wood charcoal at all sorts of temperatures, then the opponents of gun cotton, who imagine they have in powder the perfection of shooting material, are of all persons the least justified in the reproach that Baron Lenk's gun cotton is not uniform in its composition.

This want of uniformity in the composition of powder-charcoal was the origin of the tests by the Berthier process for discovering, before mixing, the component parts of powder, especially the powder-charcoal, by means of the Berthier process or trial, for the purpose of ascertaining its combustive value.

[What is here stated, with regard to the great want of uniformity of the wood-charcoal (and consequently of gunpowder), can scarcely be believed to be the real state of the case, even in Austria, where gunpowder of good character as regards uniformity, is produced; but it certainly does not apply at all to the wood-charcoal used for gunpowder in this country, which is prepared by experienced workmen under proper supervision, according to a well-regulated and thoroughly uniform system; and, which, consequently, presents in its composition a high degree of uniformity].

Unalterable quality of the Lenk Gun Cotton.

8. Even if invariability of composition in respect of gun cotton be conceded, the allegation is made, that if kept for a long time it deteriorates; the ground of this dictum being sought in experiments which show the alteration of the gun cotton to the extent of 100° with regard to litmus paper, and also are assumed to reveal a spontaneously explosive quality. The changes in the Hirtenberg gun cotton can only be ascertained direct by comparison and analysis with other and different samples of gun cotton made on the same day when manufactured, and then by repetition of analysis of the same portions of cotton after one, two, three, or more years; these results finally compared with the first year's analyses: but there exist no such analyses, because they were never made. The opponents of gun cotton themselves have therefore omitted the only true proof of a changeable quality. Such omissions can, nevertheless, be in some degree remedied.

In the magazines of gun cotton at the Neustadter Haide, there are stores of various years.

In the laboratory of the University there are samples of Hirtenberg gun cotton of three several years which have been examined by the above-named artillery officers, and they have been found not to differ materially in their composition from tri-nitro cellulose. For instance—

Per Centage.	Tri-nitro Cullulose.	No. 3 of the year 1856.		No. 6, year 1860.		No. 14, year 1862.		1862.
		1	2	1	2	1	2	3
Carbon	24·3	24·4	24·5	24·6	24·2	23·6	23·9	24·1
Hydrogen......	2·3	2·7	2·8	2·6	2·7	2·6	2·4	2·4

If these results are compared with each other, there can be no right to say that Hirtenberg gun cotton alters by keeping. They agree so far with each other as analyses of the *same material* usually do. It is to be regretted, on this as on many other accounts, that during the last twelve years such analyses were not frequently repeated. If the opponents of gun cotton, in performing an adverse experiment, heat the substance in a test tube up to 1000 C., and holding litmus paper over it, deduce from redness of the latter that gun cotton changes after long keeping, they merely prove thereby that gun cotton changes at 1000° C. Of an explosive compound, it can only be required that *it shall not deteriorate within certain limits of temperature: a requisition amply fulfilled by Lenk's gun cotton.*

Some varieties of gun cotton, if inclosed together with litmus paper in a tube, often manifest an acid reaction at ordinary temperature. This may arise from various causes. There may exist, for example, free acids. These acids may be the result of nitrogen partially oxidized, and may result from imperfectly worked cotton. This assumption granted, the phenomenon is explained, and the cause is easily avoided.

It may arise from decomposition of the gun cotton, atmospheric dampness having brought about a partial reconstitution of the cellulose.

This assumption granted, the acid reaction just adverted to should be local, affecting the material in particular spots only. This seems a necessary deduction, having regard to the long process of steeping in water to which Lenk's gun cotton is exposed in the course of manufacture. By this steeping process the cotton should otherwise be utterly destroyed.

Possibly the tetra and penta nitro cellulose are more liable to decomposition; but only traces of these bodies are to be found in Lenk's gun cotton, as experiment amply demonstrates. Were it otherwise, analyses should make known (which they do not) a deficiency of carbon and hydrogen below the theoretical quantity.

		Carbon.	Hydrogen.
Tri-nitro.........	Cellulose.	24·2	2·3
Tetra-nitro......		21·0	1·7
Tenta nitro......		18·6	1·3

But some specimens of Lenk's cotton do not even yield traces of decomposition. A parcel of Hirtenberg cotton was laid for six weeks in a pond, and not subsequently treated with potash. It was then deposited in a running stream, afterwards exposed for one month to the air; being subjected to all the various influences of dew, rain, and sun, day and night, continuously. It retains all its original explosive qualities, and fails to redden litmus paper, even though the latter be wrapped in a mass of this cotton and allowed to remain for many days. The results of an analysis of this cotton were almost identical with the calculated elements of tri-nitro cellulose, as the following table makes apparent:—

	Calculated.	Found.
Carbon	24·2	24·4
Hydrogen..............	2·3	2·8

The redness of litmus paper that sometimes occurs may also result from traces of organic acids, formic and acetic acids for example, both which may emanate from the turpentine of the pine-chests in which the gun cotton is stored.

[Some assumptions and arguments used by the Reporters under this heading, in support of the stability of gun cotton, are by no means calculated to establish that point; on the contrary, their perusal leaves the impression that the distinguished Austrian chemists are, themselves, not confident regarding the unalterable character of the gun cotton, and that certain indications of some kind of change (whether transient or continuous, remains to be proved), which have been observed by themselves, as well as pointed out by others, do not as yet admit of satisfactory explanation. It is quite beyond doubt that the completely finished gun cotton from Hirtenberg, which has undergone the most rigid purification from the acids used in its production, (or, gun cotton prepared at other places, strictly according to the system laid down by General Lenk), does exhibit an acid reaction after brief exposure to strong daylight. Ample proof has already been obtained, by the experiments carried on in this country, that an acidity will become manifest, in the perfectly purified gun cotton, during the drying process; and that this acidity remains manifest, at any rate for some considerable time

after the gun cotton has been stored in wooden or metal-lined cases, even if these are kept ventilated. These circumstances *may* prove not to be an indication of any important change in the gun cotton, but, at any rate, this is a matter which requires careful watching and the most rigid investigation, and which does certainly not admit of being explained away by a reference to possible acid emanations from pine-chests in which the gun cotton may have been stored; or, to the long-continued treatment with acids which the cotton has received (one of the leading features of Baron Lenk's system being the most complete purification from acid to which it is *afterwards* submitted, and by which its permanent characters are believed to be secured).

On the other hand, the possibility hinted at, that certain higher nitro-compounds, of which minute quantities may always exist in Lenk's gun cotton, are more liable to decomposition than the actual gun cotton; and that the acid observed may be the result of *their* change, is entitled to full consideration. Chemists who have paid attention to this subject, have some grounds for believing that, among the compounds obtainable by the action of mixed nitric and sulphuric acids upon cotton wool, the *tri-nitro cellulose* (i.e. gun cotton as obtained by Lenk's system), possesses the greatest stability].

Spontaneous Decomposition of Gunpowder.

9. These acid traces should the less evoke surprise, when we bear in mind that the gun cotton in process of manufacture had been exposed for forty-eight hours to a strong acid bath: moreover, if the subject of comparison, viz. gunpowder, be tested with equal severity, similar evidence of chemical action would be forthcoming. The courses of testing must, however, be different.

Gunpowder contains sulphur, as is well known. Sulphur being an element, cannot be decomposed: nevertheless, it is affected by the atmosphere, though slowly.

The change here is oxidation, the product being sulphurous acid. This oxidation imperceptibly affects solid cakes or bars of sulphur, but more rapidly if the sulphur be powdered. Now, gunpowder contains sulphur in the highest degree of comminution, and if gunpowder be smelt, sulphurous acid is easily perceived. Other evidence is, however, available.

The sulphurous acid resulting from decomposition of sulphur is slowly changed into sulphuric acid, which latter partly attacks the saltpetre, and is partly neutralized by the potash of the ashy parts of the charcoal.

Gunpowder has a weak alkaline action, although each of the constituents of gunpowder is absolutely neutral. The alkalinity can only result from potash contained as an impurity in the charcoal. These facts borne in mind, it follows that any sulphuric acid (resulting from sulphurous acid), developed in gunpowder, should be found united with potash as sulphate of potash. Now, the presence of sulphuric acid is easily demonstrable in affected gunpowder by the test of chloride of barium; and, inasmuch as sulphuric acid does not exist in either of the original constituents, it must necessarily be a product of decomposition.

[The reference here made to minute changes which occur in gunpowder, apparently with the object of leading the reader to infer that the acidity, noticed in stored gun cotton, is of no greater importance than they are, is certainly calculated to mislead, and might have the effect of diverting the necessary attention from a point which demands most minute examination. No chemist would suppose for an instant that the minute changes which occur in gunpowder could ever lead to a chemical action between its constituents, resulting in the generation of heat sufficient to effect the ignition of the powder; but all chemists know that gun cotton belongs to a class of bodies including many exceedingly prone to changes, which occur, in some instances, with great energy and rapidity, and are consequently

attended by a considerable evolution of heat. Hence, the detection of acid, generated in gun cotton, which was originally quite neutral, is a very different matter from the discovery of a minute quantity of sulphuric acid in gunpowder; the latter cannot affect the stability of the gunpowder, while the former may be an indication of changes, not only destructive to the gun cotton, but productive of heat, sufficient, by its accumulation, to lead to the ignition of the material].

These observations are only intended to show that no great importance should be attached to the casual reddening of litmus paper by gun cotton. Parity of reasoning should lead to the rejection of gunpowder: and, indeed, gunpowder by long exposure to atmospheric influences is so deteriorated as to be rendered wholly unfit for ballistic uses.

[This last assertion is certainly not warranted by our knowledge of the nature and properties of the two materials. The deterioration of gunpowder by exposure to atmospheric influences is well known to be due solely to the absorption of moisture by it. The remarks made on some of the statements under the preceding heading, bear likewise upon this statement].

Temperature at which Gun Cotton Ignites.

10. The rejection of gun cotton, in consequence of the changeable nature of, or the explosive quality of the material at low temperatures of the material, is so thoroughly and decidedly contradicted in the Report of Baron von Ebner, that it would be superfluous to go any further into this question; the lowest explosive temperature of the Hirtenberg gun cotton being therein fixed at 136°; a temperature which, practically, cannot raise any doubts against the use of gun cotton.

Gunpowder and Gun Cotton compared as to Temperature of Ignition.

11. Nevertheless, it is of interest to introduce something regarding the qualities of gunpowder. Mixed with sulphur, charcoal ignites at a lower temperature than by itself. A mixture of sulphur with charcoal, that had been prepared at temperatures between 150° and 400° C., begins to ignite at 250°; whereas a mixture of sulphur with charcoal, resulting from a temperature between 1000° and 1500°, when heated to 250° only burns off the sulphur, without the combustion of the charcoal.

Charcoal decomposes saltpetre at a temperature altogether different from the degree of heat at which charcoal is produced. Charcoal prepared at temperatures between 150° and 430° decomposes saltpetre at 400°. Charcoal prepared between 1000° and 1800° decomposes saltpetre at a dark-red glow heat.

Sulphur decomposes saltpetre at higher temperatures than the charcoal, namely, at about or over 432°. The temperature at which sulphur burns in the air is, according to Violette, 250°, and at this temperature gunpowder also explodes. The explosive quality of various sorts of gunpowder is different, according to the sort of charcoal used, the proportions of the mixtures, and the size and compactness of the grains. Violette observes, that an exact knowledge of the alterations in the composition of the charcoal of powder, in proportion to the temperature of the charcoaling process, must be followed by changes in the respective proportions in the mixture

of the gunpowder. It is useless to advert here to the conditions under which charcoal is here produced by the common charcoal-burners.

Is Gun Cotton Spontaneously Combustible?

12. Finally, there still remains the consideration, whether the danger of the spontaneous combustion of gunpowder is so great that it cannot be recommended for shooting purposes.

Spontaneous combustion is well defined by Lieut.-Col. Baron von Ebner, his definitions having reference to the military conditions.

Whence, then, have arisen the allegations of spontaneous combustion, and on what basis do they rest? Assuredly, they receive no countenance from the experience acquired by chemists, who in preparing gun cotton have each operated in a different manner. Pelouze maintains that the process of azotizing is finished in a few minutes. The explosive nature of the compound of this chemist, as well as that of Boucher, is therefore attributable to a composition wholly different from that of the Hirtenberg cotton.

Nor are apprehensions of spontaneous combustion deducible from any fair application of theory. Whatever theoretical objections there may be at the present time applicable, were also applicable twelve years ago. In the summer of 1862, the Simmeringer Haide explosion (already adverted to) occurred, and we may fairly assume that the list of theoretical assumptions favouring the idea of spontaneous explosion was then pretty well exhausted. In the Simmeringer Haide magazine, however, gun cotton and gunpowder were stored together. To have imputed the explosion to spontaneous ignition of gun cotton, was altogether unwarranted by evidence. With equal show of probability might it have been imputed to the spontaneous ignition of the gunpowder.

[An assertion which is not supported by any of the arguments put forth in this Report, and for which it cannot be admitted that there is any foundation].

The latter view might be supported by the experience of numerous powder explosions where not an atom of gun cotton was present, and yet the cause was never ascertained.

Many probable reasons, however, may be adduced favouring the belief that the Hirtenberg cotton did not explode spontaneously: these probabilities rest on grounds both theoretical and practical.

Experimental Proofs demonstrate that Lenk's Gun Cotton is not spontaneously combustible.

13. The history of gun cotton as chronicled by chemists and artillerists, short though the history be, is so full of records of explosion under unexpected circumstances, that an unbiassed mind can hardly fail to be impressed with the belief that amongst the ordinary conditions of military practice, there may be some competent to induce the spontaneous combustion of this material. Nevertheless, the experience of Baron Lenk, acquired during a period extending over more than ten years, is more pregnant with reliable testimony than can be found in the entire remaining history of this material.

The *manufacture* of *gun cotton* in *Hirtenberg* consists in a *number* of *perfectly harmless operations;* and it is remarkable that, contrary to what happens with gunpowder, if fire be not actually applied explosion is impossible. All operations are so arranged, that the material acted upon is in a moist or wet condition—hence not explosive. Drying takes place in a capacious building, on every side open to the air. The last process of drying is carried out in the drying-chamber, where it is effected by a stove situated on the outside, distributing its heat to the building by earthenware pipes; drying being thus insured through a gentle warmth. The gun cotton next goes either into a magazine to be packed away in chests, or is at once prepared for ammunition.

[There can be no question that the manufacture of gun cotton, according to Lenk's system, is a far safer process than the production of gunpowder, and that, provided artificial heat *is not employed* in drying the finished material, the risk of accident *in its manufacture* is infinitely less than in the case of gunpowder. But these points do not bear upon the question of the possible spontaneous combustion of the gun cotton].

In *this magazine Hirtenburg* cotton has been stored for a period of twelve years, and not a single instance of explosion has taken place. How many powder-mills have exploded in that time? In Prussia, however, a drying-chamber has lately blown up.

Your Excellency has officially been informed, that in Prussia they have worked for eight years with gun cotton, and not a single explosion has occurred except the last-named? In the Prussian drying-chamber referred to, a stove with iron smoke-pipe was used—a sufficient explanation of the misfortune.

During twelve years we have prepared gun cotton at Hirtenberg for ammunition, that is, for yarns, spun ropes, and threads twisted and woven.

One single case of explosion has occurred in the course of Baron Lenk's manufacture, the result of improper speed of working the spinning machinery. Now, the circumstance hardly need be insisted on, that gunpowder as well as gun cotton can be exploded by friction.

Gun cotton has been used for military purposes now more than twelve years: it has also been employed for mining and blasting. It has been subjected to every variety of transport. Packed in black wooden chests, it has been exposed to sunshine for months together: all this without one single accident. In the face of such testimony, it cannot be said that gun cotton manifests any tendency to explode spontaneously.

Theoretical Proofs against the Spontaneous Combustion of Lenk's Gun Cotton.

14. Those who maintain the spontaneous combustibility of gun cotton, must surely be able to base their fears on scientific grounds. Let us now examine the most important of these. And, firstly, as regards cotton itself. Cotton is chemically affected by storage, if packed damp and in bulk. It then gets heated; and examples are not wanting of warehouses burned down through fire generated by the heating of stored cotton. This chemical change in ordinary cotton begins with hydrogen, this element affording to the atmospheric oxygen, the first point of attack: hereby occurs heating, with partial oxidation. The oxidation goes on until even the charcoal is

affected, and the result may be actual combustion. This occurs not only to cotton, but linen rags, as well as to sawdust and many other organic substances. The conditions affecting Lenk's gun cotton are almost diametrically opposed to the preceding. Firstly, the three easily removable atoms of hydrogen present in ordinary cotton are disposed of by what may be called azotization; then the long process of acid-steeping involved oxidizes everything in the cotton that can be azotized; whence it follows that there remains nothing for atmospheric oxygen to act upon. Finally, slow decay, or "*eremacausis*," to which ordinary cotton is subject, cannot affect Lenk's gun cotton.

Granting that atmospheric oxygen has no influence, still the theoretical allegation may be adduced that oxygen of water is not without influence. But the Hirtenberg gun cotton lies for several weeks in water; moreover, is finally boiled with weak potash solution. Now, if it be easily changeable by water, it must surely have changed under this treatment: nevertheless, every analysis demonstrates the result to be *tri-nitro cellulose*. It may still be argued, that if oxygen and atmospheric moisture do not produce material changes, still summer heat would do so; but examples such as the black cases which have lain for months in the open air on railway stations, exposed to the direct action of the sun, and the specimen already referred to, where more than one pound of gun cotton was exposed for more than four weeks to the direct action of the sun towards the south in all weathers, retaining still its full explosive properties, demonstrate a sufficient explosive constancy. If, however, gun cotton be prepared otherwise than as in Hirtenberg—or if not prepared in Hirtenberg, according to the special instructions of General von Lenk (of which, until now, no example was before us)—then, no doubt, there might be risk of combustion as in the case of the French cotton.

[With regard to these "theoretical proofs," it is much to be desired that their *practical* soundness be tested thoroughly by searching experiments upon a sufficient scale].

How the Explosion of the French Cottons are to be accounted for.

15. The explosion can be accounted for in the following way: indeed, it has been mostly explained already.

If the acids are not strong enough, or not permitted to act sufficiently long; if, moreover, the subsequent removal and neutralization of acid be not complete, so that free acids remain; then the atoms of unremoved hydrogen may become the focus of chemical energy, which rising to a sufficient degree of intensity, may result in explosion.

To effect the perfect azotization by and contact in the first place, which the case requires, and to separate or neutralize every lingering trace of in the second place, demand time and attention to detail. We may with confidence affirm that French gun cotton differed from that of Lenk. From considerations based upon grounds already stated, it probably was not without traces of free acid.

It now remains, lastly, for us to enquire into the so-called disruptive explosibility (*vis viva*, or *force brisante*) of gun cotton.

The "force brisante" of Gun Cotton.

[The points discussed under this head, and which involve the question of the applicability of gun cotton to artillery, as a substitute for gunpowder, require a careful, systematic experimental examination].

16. This subject, purely artilleristic in its nature, can only be spoken of by chemists so far as the *force brisante* of gun cotton depends upon a certain chemical condition.

By the expression *force brisante* we understand the time within which a certain weight of an explosive material in a gun has been converted into a certain volume of gas or the volume of gas produced under otherwise equal conditions.

An explosive material is therefore the more *brisante* in proportion as the time is short for equal weight and volume of gas developed, or time and weight equal in proportion to the volume of gas is greater.

We, being accustomed to compare every sort of explosive material with gunpowder, say that gun cotton is more *brisante* than gunpowder, because the former developes an equal volume of gas in a smaller space of time—or, what is the same, time being equal, a greater bulk of gas, and, therefore, a higher mechanical effect. In the moment of explosion the result exerts a greater pressure on the barrel; hence there is more danger of bursting.

The danger of bursting by equal charges differs relatively according to the thickness of the barrel and the strength of its material to equal resistance of the shot.

Given an explosive substance more *brisante* than gunpowder, we can still fire the two with equal safety by proportionately increasing the strength of the gun. From a consideration of explosive bodies generally, it follows that each particular one, if applied to ballistic purposes, demands a peculiar gun. It cannot be reasonably expected that a gun best adapted to the use of gunpowder is also best adapted to the use of gun cotton.

If that construction be discovered, then the higher *brisante* effect of gun cotton may appear as an advantage, instead of being thought a disadvantage.

However, gun cotton can act disadvantageously in another manner on the barrel of a gun, through its higher *brisante* nature.

If we imagine the moment of the discharge of the gun taking place, then the products of the explosion—the gases, are as it were, in a mine, in which one of the resisting sides is movable, viz. the shot. The gases act with equal mechanical power on every side of the barrel in the moment before the shot is about to move. The sides of the gun being at rest (supposing it resists the explosion), it follows that part of the mechanical power is transformed in an equivalent quantity of heat, or, what is the same, the barrel of the gun will become heated; the temperature may be raised thereby so high, that the tin of a bronze barrel may partly melt, or, as we say, the barrel of the gun is "burnt out" after a number of rounds.

That the last-named effect of heat on the barrel is not to be attributed to the chemical composition of gun cotton, but to the transformation of mechanical power into heat, is proved by Lieutenant von Karolyi's analysis of the gases of combustion of Lenk's gun cotton, which he made in the

Chemical Laboratory of the Engineers' Corps Committee, as may be seen in the Report of the Imperial Academy of Science, Vol. XLVII, p. 59, Mathematical and Physical part; and which may be seen in the following table, in which the gases of combustion of powder according to Bunsen (*vide* Poggendorf, 4th Series, Vol. XII., p. 131), are cited in comparison with those of gun cotton.

Gases of combustion. Volume per cent.	Bunsen.			Karolyi.
	Sporting.	Rifle.	Common powder.	Gun cotton.
Nitrogen .... N.	41·1	35·3	37·6	12·7
Carbonic acid .... $C.O._2$	52·7	48·9	42·7	20·8
Carbonic oxide .... C.O.	3·9	5·2	10·2	29·0
Hydrogen.................. H.	1·2	6·9	5·9	3·2
Sulphur and hydrogen H.S.	·6	·67	·86	Carbon 1·8
Oxygen..................... O.	·52	—	—	Water 25·37
Light carburetted hydrogen gas	·00	3·02	2·7	7·2

If we compare the gases of gunpowder with those of gun cotton, we easily see that the chemical action of the product of combustion of gun cotton on the sides of the barrel—if there exists any action at all—must be smaller than with the use of gunpowder, because they are less oxidizing gases than those of gunpowder.

Should, therefore, bronze barrels be "burnt out" by the use of gun cotton, cast steel may be then used instead of bronze, which, in fact, has been successfully done.

Moreover, bronze gun-barrels have withstood a sufficient number of rounds by using an adequate charge of gun cotton with elongated cartridges. In this way no alteration of the bore prejudicial to the correctness of aim has taken place.

From the steel barrel of a rifle, forty rounds have been fired with gun cotton cartridges, which have hit the target 300 yds. distant in an unexceptionable manner. After the said number of rounds, the barrel was internally as clean and polished as a mirror. It appears, then, that this problem is solved in a general and satisfactory manner.

Application of Gun Cotton to Mining Warfare.

17. Gun cotton is also used for mining purposes and mining warfare. On this subject nothing but what is favourable has been reported by the Imperial Engineers (*vide* Communications of the R. K. Engineers' Committee, 1861, Vol. I., by Moritz Baron von Ebner, Colonel of the Engineers).

However, it is said that the gases of gun cotton were more poisonous in mines than those of gunpowder, and, therefore, the use of gun cotton for mining warfare is not to be recommended.

If we compare the result of Lieutenant Karolyi's analysis of the combustion gases of gun cotton with those of gunpowder as above given, we observe that both of them contain irrespirable gases; further, that they contain qualitatively the same sort of irrespirable gases; and although the

relative quantities of some of the gases from powder and gun cotton are different, the effect of those gases leads to the same practical result, viz. that after blowing up a mine, one cannot without danger approach the spot of the explosion before renewing the air by ventilation.

In this respect we may say that the gases of gun cotton will be more quickly removed by ventilation than those of gunpowder, because the first-named contain a greater quantity of gases easily dissipated; since 100 pounds of gunpowder contains 68 pounds of fixed solid matter, which alone suffices to make respiration almost impossible.

It is not probable that an explosive compound will be found which will produce any other but irrespirable gases.

It is one and the same in practice, whether a cellar contains 40 per cent. of carbonic acid and 10 per cent. carbonic oxide, or 30 per cent. carbonic oxide and 20 per cent. carbonic acid, inasmuch as no one could, without danger of suffocation, enter such a cellar.

Both the gases of gun cotton and of gunpowder, according to Karolyi, may be ignited by a match.

Recapitulation and Conclusions.

18. We believe we have in the preceding furnished replies to your Excellency to all the important questions which chemists may be called upon to decide prior to determining whether or not General Lenk's gun cotton can be used as an explosive material for warfare, and we will conclude our Report with the following general remarks:—

General Baron von Lenk's gun cotton is almost wholly made up of tri-nitro cellulose; it is manufactured in the Imperial Factory at Hirtenberg in such manner that one invariable product results.

Lenk's gun cotton remains unaltered under circumstances that would render gunpowder totally useless. It is not subject to any notable alteration, nor is it prone to spontaneous combustion. Its temperature of ignition is somewhere betweeen 130° and 160° C., sufficiently high to remove apprehension. Its *vis viva,* or *force brisante,* can be moderated without difficulty if required, or else special cannon and rifle barrels may be adapted to it.

[Of these statements, the *second* and *fourth* require, for their full substantiation, further searching experimental investigation].

The dangers in regard to mining warfare are comparatively and qualitatively the same as with the use of gunpowder,—the gases of both being irrespirable.

The manufacture of gun cotton at Hirtenberg is provisional, and General Baron W. von Lenk will know best how to devise improved mechanical apparatus when the erection of a proper factory shall be resolved upon.

According to our experience up to the present time, we recognize in the *gun cotton from Hirtenberg an improved explosive compound having many and great advantages, several of which gunpowder from its very nature can never possess.*

ON THE PRODUCTS

OF THE

COMBUSTION OF GUN COTTON AND GUNPOWDER

UNDER CIRCUMSTANCES ANALOGOUS TO THOSE WHICH OCCUR IN PRACTICE.

BY LIEUTENANT VON KAROLYI.*

[Reprinted, with permission of the Proprietors, from the Philosophical Magazine of October, 1863].

[COMMUNICATED BY THE SECRETARY, R.A.I.]

THE gun cotton manufactured according to Major-General Freiherr von Lenk's method at Hirtenberg near Wiener Neustadt, has, in consequence of special previous experiments, been used by the Genie Corps for mining purposes; and notwithstanding the fact that there are still numerous difficulties in the way of its use for gun charges, it is also used by the Royal Imperial Artillery for hollow projectiles.

The first mentioned use led the Genie Committee, to which I belong, to cause experiments to be made which are calculated to give greater insight into the chemical deportment of this substance. Among these is the attempt to ascertain the products of combustion of the gun cotton produced in Hirtenberg; and in the course of the investigation it seemed advisable to extend the method I used to gunpowder.

1. *Analysis of the Products of Combustion of Gun Cotton.*

The rapid deflagration of gun cotton, and its necessary accompaniment, the bursting action, prevented me from using in the analysis of the products of combustion the excellent method which Professor Bunsen† devised, for obtaining the combustion products of gunpowder for the purpose of analysis. It was necessary to effect the combustion *in vacuo*, and for this purpose I used a eudiometer about a metre in length, in which, instead of two wires, as in the ordinary eudiometre, a single very thin platinum wire was drawn across. To this from 15 to 20 milligrammes of gun cotton were affixed, the tube

* Translated from Poggendorff's *Annalen*, April 1863, by Dr Atkinson, Royal Military College, Sandhurst.

† Phil. Mag. Vol. XV. p. 489.

filled with mercury, and the Torricellian vacuum produced in the usual manner. By means of a galvanic battery the wire could be ignited, and hence the gun cotton exploded; thereupon all eudiometrical operations were carried out in the tube in the usual manner, after a preliminary experiment had shown that the gas produced in this manner consisted of nitrogen, binoxide of nitrogen, carbonic acid, carbonic oxide, marsh-gas, and aqueous vapour.

	Volume.	Pressure.	Temp.	Vol. at 0° and 1 m.
Original volume............	374·53	0·1156	12°	42·37
In the steam bath	415·83	0·1768	95	54·56
After absorption of NO^2	361·80	0·1078	11·2	37·47
After absorption of CO^2	328·06	0·0850	10·5	26·85
After addition of air	481·25	0·2372	12·3	109·26
After addition of oxygen	497·56	0·2510	12·5	119·41
After explosion	466·21	0·2212	11·2	99·07
After absorption of CO^2	430·57	0·1855	10·4	76·97
After addition of H ...	477·25	0·2301	11·7	105·29
After explosion	443·38	0·1983	12·6	84·08

The quantity of NO^2 and CO^2 is obtained from the absorptions, the quantity of water from the increase in volume in the steam-bath; the quantity of nitrogen is obtained from the volume 76·97, which remains after removing the carbonic acid resulting from the combustible gases, by subtracting the uncombined oxygen and the nitrogen contained in the atmospheric air added; while the combustible gases are calculated from the formulæ in Bunsen's gasometric method,

$$\text{Carbonic oxide} = P_1 - \frac{2P_2 - P}{3}, \quad \text{Marsh-gas} = \frac{2P_2 - P}{3},$$

$$\text{Hydrogen} \ldots. = P - P_1,$$

in which P is the quantity of combustible gases, P_1 the carbonic acid produced in combustion, P_2 the oxygen used in combustion.

Hence the gases from gun cotton contain in 100 parts,

	By volume.	By weight.
Carbonic oxide	28·55	28·92
Carbonic acid	19·11	30·43
Marsh-gas	11·17	6·47
Binoxide of nitrogen ...	8·83	9·59
Nitrogen	8·56	8·71
Carbon	1·85	1·60
Aqueous vapour.........	21·93	14·28
	100·00	100·00

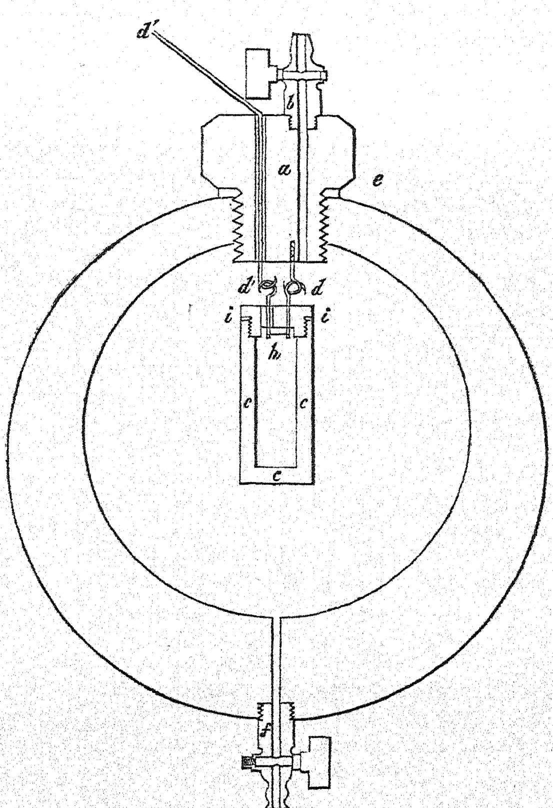
The gun cotton used had the average composition $C^{24}H^{17}N^5O^{38}$, from which, after subtracting the results of the analysis, the separated carbon is obtained which is included in the above analysis.

This simple and apparently faultless method has repeatedly shown that, by using a somewhat large quantity of gun cotton under the same circumstances, when therefore the combustion takes place under comparatively greater pressure, the quantities of the products of combustion change, and the quantity of binoxide of nitrogen diminishes as the pressure increases.

Hence the deoxidation of nitrogen-compounds during the combustion takes place the more completely the greater the work which the gun cotton has to perform during its combustion.

This circumstance suggested to me the idea of exposing the gun cotton during its combustion to a determinate resistance, and regulated so that it just gives way at the moment the gun cotton is completely burnt away. This condition led me to the experiment of placing a vessel filled with gun cotton which offered the necessary resistance, in a 60-pr. mortar, which was then exhausted and the gun cotton exploded by galvanism.

The detailed plan of this apparatus is seen from the diagram. In the touchhole of the mortar a strong iron nut, *a*, is screwed, which by the aid of a good stuffer, *e*, enables the mortar to be made air-tight. The screw is provided at *b* with a short tube closed by a cock, by which the vacuum is obtained in the subsequent operations. At *d′* a copper wire, well insulated with gutta percha, passes through the nut, while at *d* is a small hook; to this and to the insulated copper wire the vessels filled with the gun cotton intended for explosion are fixed, and, as the figure shows, allow the ignition of the charge to be effected. In the experiment the mortar is exhausted, the tap closed, and the platinum wire in the charge ignited by the current from six Smee's elements, and thus the vessel burst. It is readily seen that in this way it is possible not only to burn the gun cotton under different resistances, but also to obtain the resultant gases free from atmospheric air.



The resistance of the explosion vessels must be so chosen that the gas in the mortar, after explosion, has an excess of pressure of half an atmosphere, in order that it may subsequently be transferred to the measuring-vessels.

The explosion-vessels which I used were made according to the directions of the late Lieut.-Colonel Ebner, and consisted of hollow cast-iron cylinders closed at one end, while at the other was a nut through which the arrangement for a galvanic explosion passes. For this purpose the nut is provided with an excavation in which is a thin platinum wire fastened on the one hand to the insulated copper wire, and on the other to the copper wire which passes directly through the nut. Outside the cover the wires are bent into knots, which, as previously mentioned, serve to support the cylinders and to complete the voltaic circuit.

The weight of the gun cotton whose gases shall fill the exhausted mortar of 5216 cubic centims. contents so that there shall be the tension above mentioned, I have empirically determined, and find that it is 10 grms. The fact that 10 grms. of cotton somewhat compressed occupy a space of 10·5 centimetres in length and 2 centimetres in diameter, determined the internal dimensions of the cylinder. The thickness of the sides of the cylinder was also obtained from an empirical experiment, which showed that with a thickness of 8 millims. the cylinder just exploded with production of flame, and that thus, in accordance with the condition stated, the gun cotton burns away the moment the cylinder burst. I must here mention a peculiar circumstance which attracted my attention in determining the thickness of the side of the cylinder, and which serves to characterize gun cotton. For the above investigation I successively filled with gun cotton cylinders 4, 6, and 8 millims. thick in the side and exploded them in a hole. Although the cylinders of 4 and 6 millims. in thickness contained comparatively a larger charge, the pieces produced were considerably larger than those of the cylinder 8 millims. in thickness. The former were often only split lengthwise; their cover and bottom remained unchanged, while the pieces of the cylinder of 8 millims. in thickness were scarcely larger than hazel-nuts.

The above bursting vessels might also probably be constructed of glass. Very strong thick glass tubes are taken, and at each end corks cemented in, one of which has been provided with a galvanic conduction and the small platinum wire. The length of the vessels and the thickness of their sides could then be regulated by the quantity of gas and the desired resistance.

The qualitative analysis of the products of the combustion of gun cotton under the circumstances described gave carbonic oxide, carbonic acid, nitrogen, marsh-gas, and a trace of a sulphurous gas (probably a bisulphide of carbon compound), which, from its small quantity, escaped analysis and could only be detected by the smell. This probably arises from a small trace of sulphuric acid adhering to the gun cotton, which either was not removed in washing, or by subsequent treatment with potash remained as sulphate.

The quantitative gas analysis was made according to the following plan:—

Absorption Analysis.

	Volume.	Pressure.	Temp. °	Vol. at 0° and 1 metre.
Original volume........	114·78	0·6242	19·1	66·94
After absorbing CO^2 ...	84·88	0·6048	20·2	47·81

Combustion Analysis.

	Volume.	Pressure.	Temp.	Vol. at 0° and 1 metre.
Original volume	159·38	0·3144	19°8	46·72
After addition of air ...	238·48	0·4108	19·4	87·75
After addition of oxygen	293·77	0·4436	18·7	121·98
After explosion...........	248·16	0·3954	19·1	91·71
After absorption of CO^2	181·12	0·3504	19·5	59·19
After addition of H......	251·65	0·4344	21·6	101·32
After explosion...........	174·85	0·3389	20·4	55·15

The quantity of carbonic acid obtained from the absorption analysis =19·13. The nitrogen found by known methods is 11·37 volume. The combustible gases are determined, by the formula already mentioned in the case of the analysis in the Torricellian vacuum, as

$$\text{Carbonic oxide} = P_1 - \frac{2P_2 - P}{3} = 26{\cdot}01,$$

$$\text{Marsh-gas} = \frac{2P_2 - P}{3} = 6{\cdot}51,$$

$$\text{Hydrogen} = P - P_1 = 2{\cdot}83\,;$$

in which $P=35{\cdot}35$, $P_1=32{\cdot}52$, $P_2=27{\cdot}44$. The gun cotton used in the analysis corresponded to the formula $C^{24}H^{17}N^5O^{38}$, from which the water which cannot be directly determined, as well as the eliminated charcoal, may be found. Hence the mixture of gun cotton gases consist of—

	By volume.	By weight.
Carbonic oxide.........	28·95	29·97
Carbonic acid	20·82	33·86
Marsh-gas	7·24	4·28
Hydrogen..............	3·16	0·24
Nitrogen	12·67	13·16
Carbon	1·82	1·62
Aqueous vapour	25·34	16·87
	100·00	100·00

As previously mentioned, the bursting vessels were filled with 10 grammes of cotton, which, by an accurate measurement, was found to yield a quantity of gas of 5740 cubic centims. at 0° and 1 metre pressure. The contents of the mortar at 16° and 0·7382 metre pressure amounts to 5292 cubic centims.; the quantity of gas issuing at this pressure amounted to 2939 cubic centims.; hence 10 grms. gun cotton yielded 8231 cubic centims. at 16° and 0·7382 metre pressure. If the quantity of gas is calculated from the results of the analysis, it is found that 10 grms. of gun cotton yield 5764·2 of gases, which sufficiently agrees with the quantity actually found.

Comparing the results of the above described analysis with those of the analysis in the Torricellian vacuum, it is found

(1) That the gases in both cases are combustible from the large quantity of carbonic oxide they contain.

(2) That the gases produced *in vacuo* contain a considerable quantity of binoxide of nitrogen, while by burning gun cotton under appropriate

resistance, the nitrogen compounds are deoxidized in favour of the carbon in marsh-gas and of the hydrogen, by which an increase in the carbonic oxide, carbonic acid, water, and a separation of free hydrogen are caused. Hence it follows that the red gun cotton vapours can never occur if the entire gun cotton is burnt away at the moment in which it begins to overcome the resistance offered to it.

These facts have a practical application in the use of gun cotton to mining purposes.

II. *Analysis of the Products of Combustion of Gunpowder.*

After finding that the combustion of gun cotton under circumstances resembling those which occur in mines is of decisive influence on the products evolved, it appeared desirable to investigate the combustion of gunpowder under similar circumstances. Unfortunately, since my investigations had a specifically military object, I could only analyze the Austrian small-arms and ordnance powder; hence only a superficial comparison can be instituted with the results which Professor Bunsen obtained with freely burning sporting powder.

The combustion of the gunpowder was effected in the exhausted mortar in the same way as the combustion of the gun cotton, with the exception that, on account of the smaller action of the powder, and in order to obtain as large a quantity of gas, the exploding vessels had to be larger, but with thinner sides than those in which the gun cotton was exploded. The excavation in the cores was filled with meal powder.

The composition of the two kinds of powder used for investigation are obtained from the following analyses:—

Ordnance Powder. 4·5487 grms. gave 3·3562 grms. saltpetre and 1·1923 grm. of a residue insoluble in water. Bisulphide of carbon dissolved 0·5823 sulphur. The remainder was charcoal.

Small-arms Powder. 8·8653 grms. contained 6·8408 saltpetre: the residue of 2·0245 grms. contained 0·765 grm. sulphur, and there remained 1·2595 grm. of charcoal. The organic analysis of the charcoal, carefully freed from sulphur, gave—

For Ordnance Powder,—

Carbon	81·200
Hydrogen	2·865
Oxygen	13·599
Ash	2·336
	100·000

For Small-arms Powder,—

Carbon	82·90
Hydrogen	2·99
Oxygen	12·14
Ash	1·97
	100·000

Hence the percentage composition of both these kinds of powder is as follows:—

Ordnance Powder,—

	Nitrate of potash	73·78
	Sulphur	12·80
Charcoal.	Carbon	10·88
	Hydrogen	0·38
	Oxygen	1·82
	Ash	0·31
		100·00

Small-arms Powder,—

	Nitrate of potash	77·15
	Sulphur	8·63
Charcoal.	Carbon	11·78
	Hydrogen	0·42
	Oxygen	1·79
	Ash	0·28
		100·00

The composition of the powder analyzed by Bunsen and Schischkoff was—

	Nitrate of potash	78·99
	Sulphur	9·84
Charcoal.	Carbon	7·69
	Hydrogen	0·41
	Oxygen	3·07
	Ash	0·00
		100·00

For the qualitative analysis of the products of combustion, two cylinders were filled with the two kinds of powder, made air-tight, and successively exploded in the mortar in the manner described.

For both kinds there were found in the solid residue:—(1) sulphate of potash, (2) carbonate of potash, (3) hyposulphite of potash, (4) sesqui-carbonate of ammonia, (5) sulphur, (6) charcoal, (7) sulphide of potassium. The latter, in the case of the small-arms powder, was only formed in very small quantities.

The gaseous products of combustion were (1) nitrogen, (2) carbonic acid, (3) carbonic oxide, (4) hydrogen, (5) sulphuretted hydrogen, (6) marsh-gas, and a very small quantity of a bisulphide of carbon compound, which was distinctly recognized by its odour as being that produced in the gases from gun-cotton. The whole mixture is colourless, and contains no fume or vapour.

(a) *Ordnance Powder.*

For the quantitative determination of the products of combustion, 36·8366 grms. were used.

The gas passed into three absorption-tubes amounted to 75·3 cubic centims.; the gas issuing from the mortar until the rest was under the atmospheric pressure amounted to 5480·7 cubic centims. at 16° C. and 0·749 metre pressure; under these circumstances the mortar holds 5216 cubic centims.; hence the above quantity yielded 7621·96 cubic centims. gas at 0° and 1 metre pressure.

The absorption-analysis produced—

	Volume.	Pressure.	Temp.	Vol. at 0° and 1 metre pressure.
Original volume	90·72	0·6028	16°·2	51·63
After absorption of CO^2 and HS	53·71	0·5705	14·3	29·12

From the estimation of the potash-bulb with iodine solution, it followed that the sulphuretted hydrogen corresponded to 0·44 division. Hence the above gas consisted of 0·44 vol. sulphuretted hydrogen, 22·07 carbonic acid, and of 29·12 nitrogen and combustible gases.

The explosion-analysis of the gas freed from sulphuretted hydrogen and carbonic acid and transferred to the eudiometer, was as follows:—

	Volume.	Pressure.	Temp.	Vol. at 0° and 1 metre. pressure.
Original volume	113·26	0·2729	15°·6	28·8
After addition of air	183·36	0·3494	16·8	60·36
After addition of oxygen	204·32	0·4295	16·4	71·79
After explosion	185·62	0·3522	15·4	61·89
After absorption of CO^2	167·90	0·3476	15·1	55·31
After addition of H	224·67	0·4068	16·2	86·30
After explosion	166·38	0·3355	15·7	52·79

By applying the formulæ of the gasometric methods already mentioned in the analysis of gun cotton, since the gases are qualitatively the same, the values are obtained, for carbonic oxide $=5\cdot21$, hydrogen $=3\cdot03$, marsh-gas $=1\cdot38$, and nitrogen $=19\cdot18$.

Hence the total gas calculated for 100 parts consisted of—

42·74	vols.	Carbonic acid
0·86	„	Sulphuretted hydrogen
10·19	„	Carbonic oxide
2·70	„	Marsh-gas
5·93	„	Hydrogen
37·58	„	Nitrogen
100·00		

The determination of the solid residue in the mortar was effected, after removing the gases, by digestion with water, which was drawn off through a tap in the bottom and rapidly filtered.

The results of the analyses were as follows:—

1. *Sulphide of Potassium.* The entire filtered liquid was digested in three large boiling flasks with well-ignited oxide of copper, thereupon filtered, and the residue dissolved in fuming nitric acid. Treated with nitrate of baryta, it gave 0·1015 grm. of sulphate of baryta, which corresponds to 0·0478 grm. sulphide of potassium in the residue of 36·8366 grms. powder.

The liquid filtered from the oxide of copper was made up to 6 litres for the sake of further investigation.

2. *Carbonic Acid.* A litre of this liquid gave with nitrate of silver a precipitate of carbonate and sulphide of silver. Treated with ammonia, the carbonate dissolved, and was separated from sulphide by a weighed filter, and precipitated in the filtrate as chloride of silver by means of hydrochloric acid. Its weight amounted to 3·0475 grms., which corresponds to 0·4687 grm. combined carbonic acid; hence in the entire residue there were 2·8126 grms. combined carbonic acid.

As a control, the carbonic acid was determined by chloride of manganese by mixing a litre of the liquid with a solution of this salt which had been previously fused; a precipitate of carbonate of manganese was obtained, the carbonic acid of which, determined in the usual manner, corresponded to 2·8337 grms. in the entire residue.

3. *Hyposulphite of Potash.* The sulphide of silver (2) weighed on the tared filter, when dried at 120°, 0·2261 grm., which corresponds to 0·1733 grm. hyposulphite of potash; hence the entire residue contained 1·0400 grm. hyposulphite of potash.

A determination of the hyposulphite was also made by metrical analysis. A litre of the solution was acidulated with acetic acid, mixed with starch, and determined by means of a standard solution of iodine. A litre required

22·57 cubic centims. iodine solution; hence, according to the formula $s=a\frac{2KO, S^2O^2}{I}=t$, in which $t=22{\cdot}57$, $a=0{\cdot}000517$; this litre contained 0·1746 grm. hyposulphite of potash, and the entire residue 1·0476 grm. of this salt.

4. *Sesquicarbonate of Ammonia.* According to Bunsen's method, a litre of the liquid was boiled with caustic potash, the distillate passed into a solution of hydrochloric acid of known strength, and the hydrochloric acid which had not been changed to chloride of ammonium determined with a standard ammonia solution. I found $a=0{\cdot}04853$, the quantity of hydrochloric acid taken; $t=19{\cdot}87$, the number of divisions of an ammoniacal liquid which would have saturated a volume of hydrochloric acid equal to that taken with $t'=41{\cdot}30$ divisions of the burette. Using the formula $x=\frac{2NH^4O, 3CO^2}{2HCI}\frac{a(t'-t)}{t'}$, I found in the $\frac{1}{4}$ litre the sesquicarbonate of ammonia to be 0·041275 grm.; hence 0·9908 grm. corresponds to the entire quantity of sesquicarbonate of ammonia.

5. *Carbonate of Potash.* Subtracting the carbonic acid in the sesquicarbonate of ammonia = 0·5541 grm. from the total quantity found (2), = 2·8337 grms., there remains a quantity corresponding to the carbonate of potash = 2·2796 grms. Hence the entire residue contains 7·1498 grms. carbonate of potash.

6. *Sulphate of Potash.* A litre of the liquid mixed with chloride of barium gave 3·0244 grms. sulphate of baryta, which corresponds to 2·2683 grms. sulphate of potash for one litre of liquid, and 13·6100 grms. for the whole residue.

7. *Potash.* To determine the entire quantity of potash contained in the various salts, a litre of the liquid was carefully evaporated to dryness with sulphuric acid and ignited in a platinum vessel. 3·8466 grms. of sulphate of potash were thus obtained, corresponding to 2·0786 grms. of potash. Hence 100 grms. of ordnance powder contain 33·85 grms. of potash, which agrees closely with the result of the direct analysis of the powder. After finding, by direct observation, that 36·8366 grms. of the powder furnished 7621·9 cubic centims. of gas, the composition of the products of combustion of this powder may be stated as follows:—

Sulphate of potash	13.61
Carbonate of potash	7·14
Hyposulphite of potash	1·04
Sulphide of potassium	0·04
Charcoal	0·94
Sulphur	1·73
Sesquicarbonate of ammonia	0·99
Nitrogen	3·60
Carbonic acid	6·40
Carbonic oxide	0·97
Hydrogen	0·04
Sulphuretted hydrogen	0·10
Marsh-gas	0·15
Loss	0·07
	36·82

in which sulphur and charcoal are calculated from the deficiency.

(b) *Small-arms Powder.*

34·153 grms. were used for the combustion. The quantity of the gaseous products was obtained from the following gasometric experiments:—

Absorption Analysis.

	Volume.	Pressure.	Temp. °	Vol. at 0° and 1 metre pressure.
Original volume	136·94	0·6331	22·1	80·21
After absorbing CO^2 and SH	75·04	0·5024	21·9	40·46

If the solution of the potash-bulb is determined with solution of iodine, it is found that 0·535 division corresponds to sulphuretted hydrogen, from which it follows that the above quantity of gas consists of—

Carbonic acid	39·22
Sulphuretted hydrogen	0·53
Combustible gases and nitrogen	40·46
	80·21

The explosion analysis with the transferred gas gave—

	Volume.	Pressure.	Temp. °	Vol. at 0° and 1 metre pressure.
Original volume	120·12	0·3432	20·4	38·36
After addition of air	198·51	0·4263	20·3	78·77
After addition of oxygen	230·33	0·4478	20·5	95·89
After explosion	201·14	0·4323	19·6	81·47
After absorption of CO^2	189·46	0·4276	21·0	75·23
After addition of H	261·02	0·4817	21·2	116·66
After explosion	174·20	0·4130	18·3	67·43

If the formulæ previously used be applied, we get

Carbonic acid = 3·95, Marsh-gas = 2·29,
Hydrogen = 5·24, and Nitrogen = 26·88.

Hence the small-arms powder contains in 100 volumes—

Carbonic acid	48·90
Sulphuretted hydrogen	0·67
Carbonic oxide	5·18
Marsh-gas	3·02
Hydrogen	6·90
Nitrogen	35·33
	100·00

The solid residue in the mortar was treated with hot water and the liquid filtered. No sulphide of potassium was found to be present. The analysis was executed in the same manner as with the ordnance powder.

From the results of this analysis and from those of the gas-analysis, direct measurement having shown that 34·153 grms. of ordnance powder give

7738 cubic centims. of gas, the following scheme for the products of combustion of the ordnance powder may be given :—

Sulphate of potash	12·354
Carbonate of potash	7·096
Hyposulphite of potash	0·605
Charcoal	0·887
Sulphur	0·397
Sesquicarbonate of ammonia	0·908
Nitrogen	3·432
Carbonic acid	7·442
Carbonic oxide	0·504
Hydrogen	0·047
Sulphuretted hydrogen	0·079
Marsh-gas	0·167
Loss	0·235
	34·153

The results hitherto obtained for the products of combustion of both kinds of powder may now be compared with each other, and also with those obtained by Bunsen and Schischkoff in the analysis of sporting-powder:—

I. *Composition.*

		Sporting-powder.	Small-arms powder.	Ordnance powder.
	Nitrate of potash	78·99	77·15	73·78
	Sulphur	9·84	8·63	12·80
Charcoal.	Carbon	7·69	11·78	10·88
Charcoal.	Hydrogen	0·41	0·42	0·38
Charcoal.	Oxygen	3·07	1·79	1·82
Charcoal.	Ash	0·00	0·28	0·31
		100·00	100·00	100·00

II. *Gaseous Products of Combustion by Volume.*

	Sporting-powder.	Small-arms powder.	Ordnance powder.
Nitrogen	41·12	35·33	37·58
Carbonic acid	52·67	48·90	42·74
Carbonic oxide	3·88	5·18	10·19
Hydrogen	1·21	6·90	5·93
Sulphuretted hydrogen	0·60	0·67	0·86
Oxygen	0·52	...	...
Marsh-gas	...	3·02	2·70
	100·00	100·00	100·00

III. *Total Products of Combustion by Weight.*

	Sporting-powder.	Small-arms powder.	Ordnance powder.
Sulphate of potash	42·27	36·17	36·95
Carbonate of potash	12·64	20·78	19·40
Hyposulphite of potash	3·27	1·77	2·85
Sulphide of potassium	2·13	...	0·11
Sulphocyanide of potassium	0·30	...	...
Nitrate of potash	3·72	...	...
Charcoal	0·73	2·60	2·57
Sulphur	0·14	1·16	4·69
Sesquicarbonate of ammonia	2·86	2·66	2·68
Nitrogen	9·98	10·06	9·77
Carbonic acid	20·12	21·79	17·39
Carbonic oxide	0·94	1·47	2·64
Hydrogen	0·02	0·14	0·11
Sulphuretted hydrogen	0·18	0·23	0·27
Oxygen	0·14	...	...
Marsh-gas	...	0·49	0·40
Loss	...	0·68	0·19
	100·00	100·00	100·00
Quantity of gas for a gramme of powder	190·00	226·59	200·91

A comparison of these results shows at first sight that, on the whole, the products of combustion of powder are little dependent on the manner in which the combustion takes place. But that the composition of the powder has a great influence, is seen from the fact that in Bunsen's powder, which contains much nitre, nearly 4 per cent. of this substance are found in the residue; while, on the other hand, in the residue of the ordnance powder, which contains less nitre, almost 7 per cent. of sulphur and charcoal are separated unburnt. The influence of the composition on the nature of the products of combustion is still more surprising. Where the reducing body preponderates, the combustion of the carbon is more imperfect. Whereas the gases of sporting-powder only contain 3 per cent. of carbonic oxide, the gas from ordnance powder contains nearly 10 per cent. The quantity of hydrogen and of marsh-gas increase in the same direction, so that the ordnance-powder gas contains nearly 20 per cent. of combustible gases. Hence it is not surprising that the gases of ordnance powder, as well as those of gun-cotton, may be ignited, as direct experiment showed, by a glimmering piece of wood.

There might apparently be no difficulty, from the results of these analyses, in arriving at a right composition of powder; yet in this respect practice prefers its own empirical path. But in any case the results obtained serve as an additional proof of the inaccuracy of the view which prevails in many chemical text-books and in almost all artillery institutions,—that powder must decompose, in burning, into sulphide of potassium, carbonic acid, and nitrogen. If practice has no other reason for the composition of powder than the possibility that these products may occur, it is certainly allowable to attempt to prove experimentally that the products of combustion, even under the circumstances which prevail in practice, can never be formed alone, and that, indeed, one of them—sulphide of potassium—in many cases is not formed at all.

REPORT

OF

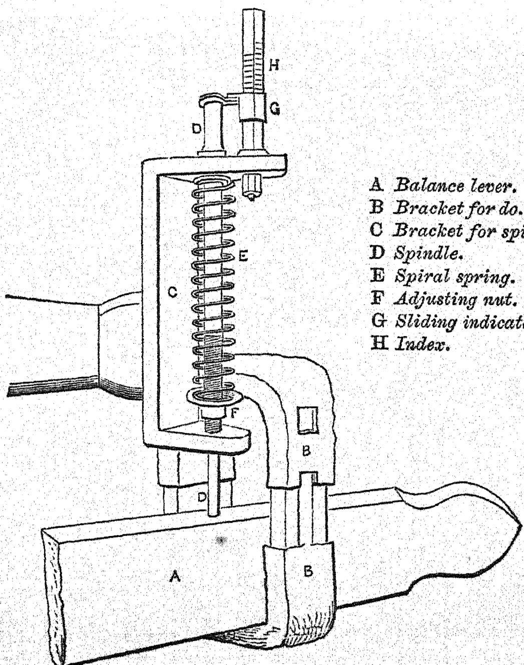
EXPERIMENTS INSTITUTED BY THE ASSISTANT SUPERINTENDENT OF THE ROYAL CARRIAGE DEPARTMENT, AT THE SUGGESTION OF THE ROYAL ENGINEER COMMITTEE, AND SANCTIONED BY THE DIRECTOR OF ORDNANCE, 29TH AUGUST, 1863, TO ASCERTAIN THE ACTUAL VERTICAL PRESSURE EXERTED BY THE VARIOUS NATURES OF FIELD AND SIEGE ARTILLERY, WHEN PASSING OVER PONTOON BRIDGES; AND ALSO WHETHER THE MAXIMUM PRESSURE IS OCCASIONED BY THE HORSES OR CARRIAGE.

BY LT.-COL. G. SHAW, R.A.

ASSISTANT SUPERINTENDENT, ROYAL CARRIAGE DEPARTMENT.

ONE of the weigh bridges in the Royal Arsenal having been selected, as affording the best means for carrying out these experiments, and it having been found that the weights of moving bodies could not be accurately ascertained without some method of self-registration the following contrivance was devised for the purpose:—

An iron spindle was dropped through a fixed bracket (*vide* Diagram), so



A *Balance lever.*
B *Bracket for do.*
C *Bracket for spindle.*
D *Spindle.*
E *Spiral spring.*
F *Adjusting nut.*
G *Sliding indicator.*
H *Index.*

as just to touch the beam when it was balanced by any stationary weight upon the bridge; it was held in this position by a collar, but was free to move upwards on the rising of the beam consequent on any additional weight coming on the bridge, which upward motion was controlled by a spiral spring, the upper end of which pressed against the fixed bracket and the lower end against a mill-headed screw nut on the spindle; by turning this nut the spring was regulated to any degree of strength. The head of the spindle was so arranged as to lift, during its upward motion, a sliding indicator on an index, which was graduated by repeated trials so as to shew where the indicator would rest for every additional hundredweight placed on the bridge.

By these means the stationary weight of any body being known and the beam weighted accordingly, the additional vertical pressure exerted on the bridge and due to the same body moving over it was accurately ascertained.

The experiments were made with the following natures of guns, mounted on travelling carriages with their full equipment of stores, viz:—

40-pr. Armstrong, 18-pr. smooth-bore, 10-inch mortar, 20-pr. Armstrong, and 12-pr. Armstrong.

Four pairs of horses with their military drivers were used to draw the two former, and three pairs for all the others; each pair with the driver weighing about 25 cwt.

In all cases they were walked over at the usual walking pace, and the mean of three trials recorded as the result.

The following is an account of the experiments:—

No. 1. 40-pr. Armstrong.

Weight of Carriage, Gun, &c.,	Stationary........	81·5 cwt.
„ „	Moving...........	106·3 „
	Increase	24·8=30 per cent.

No. 2. 18-pr. Smooth Bore.

Weight of Carriage, Gun, &c.,	Stationary........	79·3 cwt.
„ „	Moving...........	100·5 „
	Increase	21·2=26 per cent.

No. 3. 20-pr. Armstrong.

Weight of Carriage, Gun, &c.,	Stationary........	46·75 cwt.
„ „	Moving...........	61·75 „
	Increase	15·00=30 per cent.

No. 4. 12-pr. Armstrong.

Weight of Carriage, Gun, &c.,	Stationary	35·5 cwt.
„ „	Moving	53·2 „
	Increase	17·7=50 per cent.

No. 5. 10-inch Mortar.

Weight of Mortar, Carriage, &c.,	Stationary ...	63·5 cwt.
„ „	Moving	93·2 „
	Increase	29·7=46 per cent.

The high rate of increase obtained with the 10-inch mortar, as compared with those of the 18-pr. and 20-pr., was thought to be due to the low wheels (4 ft. 2 in. diameter), to prove which the same 20-pr. as used in No. 3 Experiment was mounted upon the mortar carriage wheels with the following result:—

Weight Stationary...........	44·75 cwt.
„ Moving	75·75
Increase	31·00=70 per cent.

In all the experiments the greatest elevation of the indicator took place just as the carriage wheels got fairly on the bridge, and when the horses and limber had left it; and in no case did the horses affect the indicator except in that of the 12-pr. when it was just raised through a fraction of the first space, but was greatly exceeded when the carriage came on. Small, however, as the effect thus produced by the horses really was, it is probable that it helped to create the high rate of increase as shewn by the 12-pr. carriage between whose weight and that of the horses there is not so great a difference as exists in the other carriages.

ON THE VALIDITY OF GENERAL SHRAPNEL'S CLAIM TO THE INVENTION OF SHELLS IN WHICH THE TRUE PRINCIPLE OF SHRAPNEL FIRE WAS FIRST ENUNCIATED AND APPLIED.

BY CAPTAIN VIVIAN DERING MAJENDIE, R.A.

CAPTAIN INSTRUCTOR, ROYAL LABORATORY.

In the first decade of the present century, at the battles of Roliça and Vimiera, the Royal Artillery made use, for the first time, of a projectile which then bore a different name to that by which it is now generally known. The projectile was then called "Spherical case shot,"—a proper and instructive name enough, as we shall see by and bye, but which subsequently gave way to a name which we have always believed to be even more just and proper a one than that which was first applied to it: in time "Spherical case shot" came to be called "Shrapnel shell." And the reason why this name was thought to be a better name than the first,—though, in respect to the application and character of the projectile a less instructive one,—was this: It seemed to those who sanctioned its adoption that to connect the name of the officer who invented the shell inseparably with it, so that whenever men spoke of the projectile they could not choose but name, and thus in a sort of way acknowledge, its inventor, would be to erect a suitable and imperishable monument to the inventor's fame;—and the monument appeared the more suitable and desirable because the officer had received from the Government no pecuniary reward for his invention, and his family not being a rich one, it seemed probable that failing this monument he would have none at all.*

Thus "Spherical case shot" came, and in the eyes of all English artillerymen came very properly and appropriately, to be called "Shrapnel shell," after the inventor, Henry Shrapnel, of the Royal Artillery.

It is not perhaps very generally known that the validity of General Shrapnel's claim to the invention has been disputed, by some foreign authors whose names and words ordinarily carry weight on the subjects which they treat. Such, nevertheless, is the case; and it will perhaps not appear an

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* The following extract from the Reports of the Select Committee explains how and when this name came to be officially given to the shell:—"2nd June, 1852. Report of the Committee on Mr Shrapnel's letter of the 17th May, 1852, requesting, on behalf of the family of the late General Shrapnel of the Royal Artillery, the honour of the Board issuing an order that the *spherical case shot* be called *shrapnel shells* instead of spherical case by some and shrapnel shells by others, from the circumstance that other nations have long since done this honour of invariably attaching his name to this weapon, and because the family have not the means to afford the expense of erecting a monument awarded to the graves of other distinguished officers, but which such a distinction would be the means of representing.

"The Committee see no objection to this application of Mr Shrapnel, and solicit your Lordship's authority for his request being granted."—*Synopsis of Ordnance Select Committee Reports.—Shrapnel shells*, pp. 83, 84.

altogether unprofitable expenditure of time and trouble to investigate the claims thus set up, and to see what can be said on behalf of the brave old General who can no longer speak for himself, and to whom it is no longer permitted to vindicate his own claim.

It seems to me that if his title to his shell be General Shrapnel's only monument, and the one which his family, who best knew what his wishes would be on this matter, selected for him, upon *us* has devolved in some sort the custody of it, and we are bound to guard it jealously from those who would deface it, by scribbling upon it other names, and by obliterating the one which we are in the habit of thinking should be there alone.

In short, was General Shrapnel the inventor of the shell, or class of shell, which bears his name, or not?

The term "inventor" is variously applied: men are sometimes called inventors who rake up some forgotten principle or design long since laid aside; or who import into their own country without acknowledgement the little known inventions of other lands; or who lay hold of a principle imperfectly applied, and walking up the ladder which another man has laboriously constructed, proceed to build above his head on their own account, maturing his defective or incomplete details, and associating their own names with the first practical application of the principle; or who first perceive the principle but fail to apply it usefully; or who gather together fragments and shreds of other men's inventions, and build up a whole of their own,—all these men are sometimes called inventors. But there are inventors of another, though less numerous, class,—less numerous because the process by which they acquire their title, being a sort of double process, is slower and more laborious:—these are the men who first clearly perceive and appreciate the principles upon which the operation and success of their own invention will depend, and who first apply these principles practically and in a useful form. It is among inventors of this latter class that I desire to rank General Shrapnel; it is his title to be ranked among inventors of this class that the foreign authors I have referred to dispute.*

It will be necessary before proceeding to discuss General Shrapnel's title to be considered as the inventor, in the broad sense which I assign to the word, of the shell which bears his name, to establish clearly; (1) What was the nature and proposed application of the shell; (2) What the principle of action upon which that application depends.

1st. *The nature and proposed application of the shell.* The Shrapnel Shell "originally consisted of a thin iron shell filled with musket or carbine balls, sufficient powder being inserted, with the balls, to cause the bursting of the shell when ignited by the fuze."†

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* I have nowhere seen it disputed that the credit of perfecting, or procuring the re-introduction into the service of, shells of the Shrapnel class is due to General Shrapnel; so much, at least, seems to be *universally* admitted. But it will be seen by my text that the credit thus accorded appears to me to involve a much lower order of merit than that to which I think the General has a claim, and which this paper is written to establish.

† *Synopsis of Ordnance Select Committee Reports.—Shrapnel Shell*, p. 5.

It was intended, not to supersede case or grape but, *to act as case or grape at longer ranges than were attainable with those projectiles*;* and its character was thus defined with great exactness, as I have already indicated, by the name which was first applied to it, of "Spherical case shot."

2nd. *The principle of action of the shell.* The shrapnel shell acts as follows:—It describes a path similar to that of an ordinary spherical projectile up to within a short distance of the object aimed at, when, if the fuze be properly adjusted, the shell will be exploded, the bullets and fragments continuing their forward course with a communicated velocity equal to that of the shell at the moment of fracture, and describing, as they slightly disperse, "a curved cone, the apex of which is at the point of explosion."† The effect of the shell, it will thus be seen, *depends in no way upon the bursting charge, which should merely be sufficient to open the shell, and not sufficient to cause any dispersion of the bullets and fragments*,‡ *but entirely upon the velocity communicated to the pieces by the shell at the moment of rupture.* There is, therefore, as has been well said, this characteristic difference between a Shrapnel and a Common shell, "that the former produces its effect by means of the charge of the piece; the latter by means of the charge of the shell;"§ and the principle involved in this distinction is, in fact, the leading principle of the Shrapnel shell.

We may now proceed to examine General Shrapnel's claim to be considered as the first who clearly perceived and appreciated this principle; and who first practically and usefully applied it.

An overwhelming mass of evidence might be produced to shew that the large majority of authors and others have unhesitatingly accorded to General Shrapnel the credit of the invention;|| but we have not now to do with

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* "Shrapnel shell.........were not intended to supersede the case or canister and grape shot, which are still in the service, but to be used at distances beyond the ranges of case and grape."—*Synopsis of Ordnance Select Committee Reports.—Shrapnel Shell*, p. 5.

Col. Shrapnel himself thus speaks of his invention: "The object now accomplished is the rendering the fire of case-shot effectual at all distances within the range of cannon."—*Ibid.* p. 6.

"Shrapnel is case shot extended."—Authorized *Manual of Artillery Exercises*, p. 17 (Ed. 1860).

† Col. Boxer's *Remarks upon the Diaphragm Shrapnel Shell*, p. 54. See also, *Observations on Shrapnel Shells*, by Major Seton, p. 38; and the chapter (p. 25) headed, "Some remarks on the theory of shrapnels." See also *Expériences sur les Shrapnels*, par Decker, p. 22, *et seq.*

‡ "The charge of powder .... is small, just sufficient to open the shell."—Major Seton's *Observations on Shrapnel Shells*, p. 37.

"The bursting powder acts exclusively on the containing case or shell without at all affecting the contained bullets."—*Ibid.* p. 38.

"The projectile is so arranged that the bursting charge shall merely relieve the bullets, without affecting in any degree their onward motion."—Col. Boxer's *Sandhurst Course*, p. 20.

"That the bullets when relieved, shall be but slightly affected on the direction of motion of the shell, by the action of the bursting charge............ *This condition embodies General Shrapnel's grand principle.*"—Col. Boxer's *Remarks on Diaphragm Shrapnel Shell*, p. 26.

I have thought it desirable to establish this very important point by selecting some passages upon the subject, from the many available, and quoting them here in support of my text.

§ Major Seton's *Observations on Shrapnel Shells*, p. 38. See also Decker's *Expériences sur les Shrapnels*, p. 22.

|| It may be interesting to quote some of the testimonies, which I have culled from different

testimonies in his favour, but with the claims which have been put forward on behalf of other nations. These claims are two in number: the first is a claim which has been preferred by General Bormann of the Belgian army, on behalf of the Germans of the 16th Century; the second is a claim preferred by the celebrated Piobert on behalf of the French artillerists of the 17th Century. These claims I shall proceed to investigate in succession:

(1) THE GERMANS CLAIM TO THE INVENTION.

General Bormann's work on *The Shrapnel Shell in England and in Belgium,* commences with the following passage:—"The English were the first nation who, in modern times, employed the projectiles known in England more under the name of 'spherical case shot,' than under that of shrapnel; hence generally, though erroneously, as we shall see hereafter, its invention is believed to be of English origin."—*Shrapnel Shell in England and Belgium,* p. 1.

The ground upon which General Bormann disputes General Shrapnel's claim to the invention is, that the shrapnel shell was merely, as he believes, the application of a principle perfectly well known to the German artillerists of the 16th Century, and applied by them in the form of a projectile termed, *hagel kügel* (hail shot). This is what General Bormann says upon the subject:—"The shrapnel shell is a German invention of the 16th Century, as has lately been discovered. For this discovery the Germans are indebted to a distinguished officer of the Royal Prussian Artillery,

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works, in General Shrapnel's favour. I have selected those which are concise and best adapted for quotation, and which appear to me to be the most weighty: to these a large number of other quotations of a similar nature might be added, but those I have given will suffice for my purpose:—

"This invention has universally been accorded to General Shrapnel of the British Artillery."—*Ordnance Select Committee Report on Shrapnel Shells*, p. 5.

"Shrapnel shells.........take their name from that of the inventor, the late General Shrapnel, of the Royal Artillery."—*Observations on Shrapnel Shells*, p. 9.

"Shells originally introduced by General Shrapnel."—Owen and Dames' *Lectures on Artillery*, p. 69.

"Although General Shrapnel's invention of spherical case shot dates from the beginning of the present century," &c.—*Report of American Ordnance Commission to Europe*, p. 167.

"Shrapnel's shells, or spherical case: The author of the *British Gunner*, has very justly observed that the latter term is given to the prejudice of the ingenious inventor Major General Shrapnel." *Aide Memoire to the Military Sciences*. (See also *The British Gunner*. Introductory Remarks).

General Foy in his *Historie de la gurre de la Peninsule*, Vol. I. p. 298, speaks of "Shrapnel spherical case shot from the inventor's name, Col. Shrapnel."—*Observations on Shrapnel Shells*, p. 71.

Paixhans in his *Constitution Militaire de la France*, p. 248, speaks of them as having been "proposed by Shrapnel, an English Artillerist."—*Ibid.* p. 70.

"Colonel Shrapnel of the Royal Artillery, has the exclusive merit of having added this formidable weapon to those already in use," &c.—James' *Military Dictionary*, p. 813.

"The military weapon, which, as I have said, my father had for some time patronized, and endeavoured to introduce, was a kind of shell, invented by an ingenious Officer of Artillery, Lt.-Col. Shrapnel, and now familarly known by the name of *Spherical case shot*."—*Memoirs of Sir John Sinclair*, by his son, the Rev. John Sinclair, M.A. Vol. II. p. 243.

"To that able and distinguished officer (Major-General Shrapnel), is due the credit of the invention which has made his name so justly celebrated."—*Naval Gunnery*, p. 425.

See also opinions of Decker and Meyer quoted further on.

Captain Toll, who in his historical researches found in the library of the Heidelberg university, a MS. of the year, 1573, which incontestably proves: that the German artillerists of that epoch knew perfectly well the principle upon which the present shrapnel fire is founded, and that notwithstanding their limited means, they had even succeeded in the application of this projectile, which was then called *hagel kügel* (hail shot)."—*Shrapnel Shell in England and Belgium*, pp. 59, 60.

Artillerymen, however, will probably not think the proof as "incontestable" as General Bormann appears to consider it, when they read the description which he gives of the projectile in question. "This *hagel kügel consisted of a leaden shell, or rather box, of cylindrical form;* its fuze was the old common fuze placed in the axis of the shell and at one end of the cylinder; the bursting powder surrounded and covered the fuze in the interior of the shell; the rest of the empty space of the shell was filled up with 'hail,' pieces of iron, bullets, or even pebbles; and lastly, the shell was suitably closed at the other end. This projectile was introduced into the gun so that its fuze was turned towards the charge of the piece; the fire with it seems to have been successful to such a degree that it was employed in action."—*Ibid.* p. 61.

It is perfectly evident from this description, that the *hagel kügel* was merely a clumsy description of case, only adapted for short ranges; for it would of course be impossible to project a *cylindrical* leaden box to any considerable distance from a smooth-bore gun.*

It is possible, therefore, that the *hagel kügel* may have had something to do with the introduction of case, but that it gave any hint as to how case might be made effective at *long ranges* cannot be conceded; and it has already been explained that *it is only at long ranges that shrapnel is superior to case; herein alone the great advantage claimed for it lies—that it enables a fire similar to that of grape or case to be delivered at distances beyond the ranges of those projectiles.*

It is difficult, therefore, to see how the principle of the Shrapnel shell, much less the application of the principle, can be fairly said to have been derived from the *hagel kügel*, when the characteristic feature of the former—the great advantage upon which its claims to notice were founded, viz. that it enabled case effects to be produced *at long ranges*, was necessarily, from its form and construction, absent in the latter.

(2) THE FRENCH CLAIM TO THE INVENTION:

Piobert says:—"Les projectiles creux ont été employés, notamment à Lille en 1672 a lancer des balles de plomb en grande nombre et à grandes

* It might appear at first sight to the modern artilleryman that the fact of the fuze and bursting charge of the projectile being "turned towards the charge of the piece," affords an additional reason for supposing that the projectile was intended to burst soon after quitting the gun. I have not overlooked this consideration, but I do not think it *proves* anything; for there is no doubt that in those times the fuzes of *shells* were frequently turned towards the charge, and clearly, *shells* could not have been intended to burst invariably on quitting the muzzle. The explanation of this arrangement is probably to be found in the fact that the artillerymen of those days did not know that the flash of the discharge would ignite the fuze if placed away from it.—See *Le Passe et l'Avenir de l'Artillerie*, Vol. III, p. 342, *ante, et seq.*

distances. Pour cela on introduit dans leur intérieur une certaine quantité de balles indépendamment de la charge qui doit produire l'éclatement, et l'on place dans l'œil une fusée d'une longuer telle que le feu ne se communique à la charge qu'un peu avant l'arrivée au but."—*Traité d'Artillerie, Théorique et Pratique*, p. 253.

Piobert does not, it is true, say in so many words that the true principles of shrapnel fire were understood by those who proposed and employed these projectiles in the 17th Century, but he implies it. He implies by the bare fact of introducing a description of this projectile in connexion with his account of shrapnel shells; and he implies it more pointedly by the very precise description which he gives of the action of these shells and of their bullets;* this description being surely intended to convey two things to the mind of the reader,—the first, that the action of the projectiles was the same as that of the modern Shrapnel shell (and we *now* know that fired and exploded *under the same conditions* it must necessarily in its main effects have been the same),—the second, and the more important, that the inventors of the shell and the artillerymen who used them thoroughly well understood their action, and the principle upon which that action depended;—in short, that *theoretically* and *practically*, spherical case shot were understood more than a century before General Shrapnel proposed them; and that the credit of the invention belongs not to that officer, but to the artillerists of the time of Louis XIV.

Piobert's statement has been adopted by some other authors: Thiroux says, "*Des Schrapnells* ou *obus a bàlles*: Ces projectiles, essayés en France, dès le temps de Louis XIV, au siége de Lille."—*Instruction d'Artillerie*, p. 299; and Captain Brenton in his Course for the American Cadets, in the same way, dates the first employment of these projectiles as far back as the time of Louis XIV: "Projectiles similar to spherical case shot were used in France as early as the time of Louis XIV."—*American Artillery Course*, p. 77.

Now with regard to Piobert's statement, (upon which apparently the other two that I have quoted are built), I would first observe that I have been unable to trace the authority upon which it rests. Ordinarily Piobert is very particular in supporting his statement by references to the authors from whom his authority is borrowed; in this instance he fails to do so. In the absence of any such references I have searched a number of other works upon the history of Artillery; particularly, the admirable *Le Passe et l'Avenir de Artillerie*, perhaps the most correct and authoritative work upon the subject which has ever been published; neither this work, nor, with one exception, any of the others which I have consulted, make any mention of such a projectile as Piobert describes.

The one exception is Decker, who in a note says "Dans l'ouvrage de Geissler (Curieuse und Velkommene artillerie) de 1718, on lit., page 90, que Geissler a tiré ces bombes, le 20 Novembre 1642, à la citadelle de Lille, en présence de Louvois et du Grand-Maître de Lude."—*Expériences sur les Shrapnels*, p. 13. It is probably, then, upon *Geissler's* authority that Piobert's statement is founded; but that this authority rests upon no very

* I have not thought it necessary to quote this description; it is exactly the description which the modern artilleryman would give of the action and principle of the shrapnel shell.

solid or well-established basis may be concluded from the remark made by Decker a little further on: "*Il n'y a que l'expérience de Geissler . . . . : mais qui en garantit l'authenticité?*"—*Expériences sur les Shrapnels*, p. 14.

But supposing it could be incontestably established that "des bombes remplies de balles de plomb" *were* fired at the siege of Lille, does this fact of itself deprive General Shrapnel of the credit of the invention? In my opinion certainly not. To my mind the absence of any mention of these projectiles in the numerous works treating of the history of artillery (with the exceptions I have mentioned) is convincing proof that although projectiles resembling Shrapnel shells may have been used in the 17th Century they were not intended to serve the same end as General Shrapnel's shell *and were constructed on a different principle.*

I believe that the bullets were placed inside to act merely as so many additional splinters, the effect of which, according to the idea of the inventor, would depend upon the same causes as the ordinary splinters of ordinary shells, viz. upon the bursting charge of the shell, and in no way upon the communicated motion of the projectile, and the velocity with which it might be travelling at the moment of rupture; while, doubtless, in addition, their weight was thought advantageous as increasing the density of the projectile.

My reasons for holding this opinion are as follows:—

1st, The first appreciation and application of so important a principle in gunnery as that involved in the proper action of the Shrapnel shell, would surely not have been passed over without remark by the authors of the military histories of those times.

2ndly, If the principle had been known to the artillerists of this epoch, it seems strange that no further efforts should have been made to apply it more successfully than in these first rude attempts, and that a century and a quarter should have elapsed before the subject was again practically, or, for aught we know, theoretically, taken up.

3rdly, All difficulty in accounting for the disappearance of projectiles of the nature described by Piobert, and for the absence of any mention of them in the works to which I have alluded, vanishes if we adopt the explanation suggested above, that the bullets were placed inside to increase the weight of the projectile and to act as so many additional splinters, for a very slight experience,—the experience which one siege may have afforded,—must have served to show that shells of this construction, and intended to act on this principle, were of little real service. And the complete failure which must have speedily followed any attempt to introduce shells constructed on these erroneous principles would sufficiently account for the absence of any general mention of them, and of any attempt to improve upon them—facts which I know not how to account for in any other way.

4thly, There is no doubt that shells *have* been thus constructed,—contructed, that is to say, with a number of bullets added to them with the object of increasing the number of splinters, for the following passage occurs in an old work written sometime in the 17th Century, by Casimir Simie-

nowicz, a Polish Officer, and called *The Great Art of Artillery*:* "This Grenado is most frequently armed with Leaden Bullets; that is the outside of it is covered with them, that it may do the greater execution. In order to do this, you must first coat the Grenado with melted wax, which must have a certain quantity of colophone† mixed with it; into which you may sink as many Musquet Balls as you please whilst it is cooling: then wrap the whole up in a cloth and bind it well round with packthread."—*The Great Art of Artillery*, p. 212.

This passage removes all doubt as to the fact that shells *have* been constructed upon the erroneous principle which I have explained; for, in the first place, the "grenados" in question were *hand* grenades, and as these could not have been thrown with sufficient velocity to communicate an effective forward velocity to the bullets after rupture, clearly the bullets must have derived their effect from another agency, and that agency must have been the bursting charge of the shell; and, in the second place, the fact of the bullets being placed *outside* the shell seems to point towards the same conclusion, for by placing them outside, the whole of the interior of the shell became available for the reception of the bursting charge, and as, according to my view, the effect of the bullets depended upon the bursting charge, by this arrangement that effect would be proportionally increased.

5thly, That the leading principle of Shrapnel fire—the theory of the projectile, if I may so designate it—had not made a very permanent impression on the minds of the French artillerists of the 17th Century, if it *had* ever been known to them, must be concluded from the fact that it was *unknown* to French officers of the highest rank and experience in the 18th and the beginning of the 19th Centuries! That this was the case is placed beyond all doubt by a note appended to Decker's *Traité Elementaire d'Artillerie*, by the French translators, Colonel J. Ravichio de Peretsdorf and Capt. A. P. F. Nancy: "Ces projectiles ne peuvent pas être, à beaucoup près, aussi terribles qu'on les représente. Les balles n'etant point serrées sur la petite quantité de poudre renfermée dans l'obus, *celle-ci ne peut leur communiquer, par suite de l'explosion, une quantité de mouvement capable de les porter assez loin et avec assez de force pour les rendre vraiment meurtrières*. Des expériences faites à Vincennes sout venues à l'appui de ce raisonnement, et ont démontré que les *Schrapenschels* étaient réellement de fort peu d'effet. Pour les rendre plus meurtriers, un officier Français a proposé de les composer de deux enveloppes concentriques en fer coulé, entre les quelles seraient placées les balles, et dont celle de l'intérieur contiendrait la poudre. Il n'est pas douteux que de cette manière la force de l'explosion ne communiquât aux balles une quantité do mouvement beaucoup plus considérable, et ne les rendit par conséquent beaucoup plus meurtrières; mais aussi la fabrication en deviendrait certainement beaucoup plus difficile

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* This work is, I believe, very rare. I am indebted to Colonel Lefroy for the loan of a copy of the English translation, (the original work was in Latin), published in 1729. There is a copy of the work in the Royal Artillery Library, at Woolwich.

† Powdered rosin.

et plus coûteuse." I think I am justified in concluding from this passage that the theory of the projectiles "was unknown to French officers of the highest rank in the 18th and the beginning of the 19th Centuries," when it is remembered that Colonel Peretsdorf was a "Chevalier des ordres royaux a Saint-Louis et de la Légion d'Honneur, Archiviste des bureaux de l'artillerie et du génie au ministère de la guerre, &c.," and who has served he tells us, "en Piémont, puis en Antriche, et enfin en France, et ayant, dans sa longue carrière militaire, occupé tous les grades depuis ceui d'élève d'artillerie, et rempli presque tous les emplois, soit en paix, soit en guerre, soit dans le personnel, soit dans le matériel;" while Captain Nancy was "Aucien élève d' l'école polytechnique, de la société des lettres, sciences, et arts, de Metz," &c.

This passage also conclusively proves that the idea of those officers respecting these projectiles was exactly the idea which I have attributed to the French artillerists of the 17th Century, viz. that the bullets were intended to act as so many splinters, to which force and movement would be communicated *by the bursting charge, and without reference to the velocity of the shell.* This seems to me to be very strong presumptive evidence in support of the theory which I have advanced.

From these considerations I have concluded that the principle of the shrapnel shell had not been perceived, and still less appreciated, as Piobert would have us suppose, by the artillerists of the 17th Century. Those to whom my reasoning upon this subject does not carry conviction I would refer to the following extract from Decker respecting the history of these projectiles, and I must congratulate myself in being able to quote so distinguished an author in support of my views: "Quant à ce qui concerne les shrapnels, on recontre bien dans l'ancienne artillerie quelque chose de semblable *mais fondé sur un tout autre principe;* ce qu'il ne faut pas confondre.

"On s'est servi de cylindres remplis de charges explosives et de petites balles non pas probablement, d'après le principe des shrapnels, mais comme une sorte de pétards; toutefois, nous connaissons aussi peu l'usage spécial de ces projectiles que la matière des petites balles.

"On dit qu'au siege de Rhodes, en 1522, les Turcs, se sont servis de bombes remplies de grenades; c'est là l'exemple le plus ancien d'un projectile, qui a une affinité éloignée avec les shrapnels moderne.

"Dejà le célèbre Furtenbach propose, en 1629, de placer sur les fusées un pétard ou une grenade, et de les remplir avec des balles de fer ou de plomb pour leur donner l'effet destructif d'un tir à mitraille.

"Dans l'année 1697, le colonel Geisler a tiré à Telle, devant le ministre Louvois, des bombes remplies de balles de plomb; et, dix ans plus tard, il s'est servi de bombes remplies avec des grenades à main.

"En 1774, on rencontre dans l'artillerie Prusienne, parmi les projectiles à obus, des *boulets explosifs,* qui contenaient de petites grenades; on dit que ces grenades, après l'explosion du boulet, étaient lancées à 80 pas et faisaient explosion à leur tour.

"Il est vraisemblable que ces projectiles étaient les mêmes que ceux qu'on a depuis nommés *perdreaux.* En l'année 1806, un grand nombre de ces projectiles tomba dans les mains des Français à Magdebourg, et en 1813,

lorsque les munitions devinrent rares, ils nous ont canonnés avec, probablement sans en connaître la construction; j'y étais, et j'ai souvent été interrogé par les camarades sur ce fait singulier.

"Si on voulait se donner beaucoup de peine pour faire des recherches ulterieures, on rencontrerait probablement plusieurs faits qui rentreraient dans le domaine des shrapnels; mais quelques expériences que l'on eût faites dans les temps passés avéc des projectiles simulant des shrapnels, elles sont indifférentes pour notre but; il n'y a que l'experience de Geisler qui puisse faire exception: mais qui en garantit l'authenticité? *Tous les projectiles creux avaient cela de commun que leur effet devait dépendre de la charge explosive, et le colonel Shrapnels fut le premier qui s'attacha à la vitesse initiale du projectile, et la prit pour base des obus à balles. Cette seule circonstance suffit pour lui assurer la priorité de l'invention, et le mettre à l'abri de toute contestation.*

"'Tous les projectiles remplis de balles de plomb et de poudre, jusqu'au temps de Shrapnels, dit le capitaine Meyer, ressemblaient aux shrapnels seulement dans leur composition générale, mais non dans leur composition spéciale, *et moins encore dans leur but;* car tous les projectiles creux des temps anciens ne devaient avoir de l'effet *qu'après avoir touché le sol, tandis que ce qu'il y à de caracteristique dans les shrapnels consiste dans l'explosion du projectile en avant de l'ennemi. Les anciens projectiles projetaient leurs balles par la force de la charge d'explosion, tandis que les shrapnels les projettent par la charge de la pièce;* les premiers ne sont que des projectiles creux dont le nombre des éclats est augmenté, et les derniers sont des balles devant agir au loin. L'effet des anciens projectiles de cette espèce devait être faible; de là leur emploi rare. Avant que les fusées n'eussent atteint assez de perfection pour être réglées avec précision, a quoi l'on est parvenu seulement vers la fin du dernier siècle, il ne pouvait pas être question de produire l'effet que Shrapnel avait en vue; et c'est là le mérite incontestable de Shrapnel d'avoir tiré parti du perfectionnement des fusées pour utiliser un effet de cartouches non connu jusque-là.'"—*Expériences sur les Shrapnels* pp. 12—14.

Major Seton in his little work upon the Shrapnel shell, also has a passage upon the subject, which I shall do well to quote. "It may be stated, however, that these shells were filled with leaden bullets at the early periods above-mentioned, under an erroneous notion, that, on the shell bursting, the contained bullets would scatter with force and produce an effect similar to that of splinters of the shell. The dynamical fact, however, of the bullets continuing to pursue the course the shell was moving in when it burst, and that they derive their effect rather from the charge of the piece than from that of the shell—the leading principle in the shrapnel fire—appears, no doubt, to have been first clearly perceived, as well as distinctly enunciated, by Colonel Shrapnel."—*Observations on the Shrapnel Shell*, p. 10, *note.*

The conclusions to which I have come, then, after a careful investigation of the facts of the case are, that General Shrapnel's invention had not, either in theory or practice, been anticipated by either the Germans or the French, or, that I can discover by any nation in any age.

It is not enough, as I have before said, that General Shrapnel should merely

be spoken of as having "improved upon," "re-introduced,"* or "perfected,"† a shell invented by Germans or French some hundred of years back. I desire to see his claim to the *invention,* universally and unhesitatingly conceded. If it should appear that I have opposed successfully the adverse claims which have been put forward, or if I have in any way contributed to establish on a firm basis the title of our English artillerist to the full merits attaching to this important invention, I shall not regard the time which the investigation has necessarily occupied as otherwise than well spent.

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* "Remit en usage." *Piobert,* p. 253.
† "Perfectionnés," *Thiroux,* p. 299.

NOTE ON THE RATIO

BETWEEN

THE FORCES TENDING TO PRODUCE TRANSLATION AND ROTATION IN THE

BORES OF RIFLED GUNS.

BY CAPTAIN NOBLE, late R.A.

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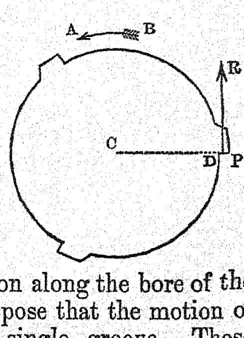
THE magnitude which the rifled ordnance of the present day have attained, and the large charges which are consumed in their bores, render it an object of great interest that we should be able to assign the pressures on the grooves (or other driving-surfaces intended to give rotation) due to different modes of rifling, as well as to determine the increment in the gaseous pressure arising from the nature of rifling adopted.

The formulæ, which we shall hereafter give, have, with slight modifications, been used at Elswick for nearly three years, and are now given, partly, because no investigation of the question has, to our knowledge, been published, and partly because, as several erroneous statements on the subject have appeared, the formulæ themselves may possibly be of use to some artillerists.

The case we shall first examine will be that in which the rotation is given by means of grooves, the driving-surfaces of which are such that if a section of the gun, perpendicular to the axis, be made, the line drawn from the centre of the bore to the groove is coincident with the section of the driving-surface. A section of such a form of rifling is shown in fig. 1. The reader is supposed to be looking from the muzzle towards the breech of the gun, and the direction of rotation is shown by the arrow *AB*. It will be seen that the radius *CD* is coincident with the section of the driving surface *DP*.

Fig. 1.



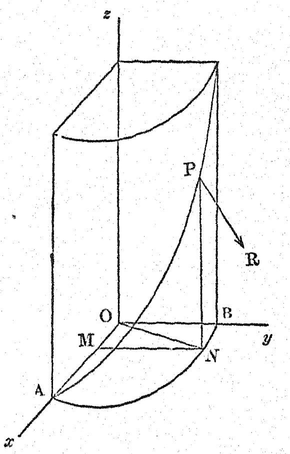
In entering upon this investigation, it will be more convenient to consider the projectile in its motion along the bore of the gun as moving on a fixed axis, and, further, to suppose that the motion of rotation is communicated to the projectile by a single groove. These suppositions will not interfere with the accuracy of our results, and will enable us very much to simplify the equations of motion.

Take (fig. 2) as the plane of xy, the plane passing through the commencement of the rifling at right angles to the axis of the gun. Let the axis of x pass through the groove under consideration, and let the axis of z be that of the gun. Let AP be the helix, and let (see figs. 1 and 2) $P(x, y, z)$ be the point at which the resultant of all the pressures on the groove may be assumed to act, the projectile being in a given position. Let the angle $AON = \phi$.

Let us now consider the forces which act upon the projectile. We have, firstly, the gaseous pressure acting on the base of the shot. Let us call this force, the resultant of which acts along the axis of z, G. Secondly, if R be the pressure between the projectile and the groove at the point P, this pressure will be exerted normally to the surface of the groove, and if we denote by λ, μ, ν the angles which the normal makes with the co-ordinate axes, the resolved parts of this force will be

$$R \cos \lambda, \quad R \cos \mu, \quad R \cos \nu.$$

Fig. 2.



Thirdly, if μ_1 be the coefficient of friction between the rib of the projectile and the driving-surface, the force $\mu_1 R$ will tend to retard the motion of the projectile. This force will act along the tangent to the helix which the point P describes; and if α, β, γ be the angles which the tangent makes with the co-ordinate axes, we have as the resolved portions of this force $\mu_1 R \cos \alpha$, $\mu_1 R \cos \beta$, $\mu_1 R \cos \gamma$; and summing up these forces, we have the forces which act

$$\left.\begin{array}{ll} \text{parallel to } x = X = R(\cos \lambda - \mu_1 \cos \alpha), \\ \quad\text{,,} \qquad y = Y = R(\cos \mu - \mu_1 \cos \beta), \\ \quad\text{,,} \qquad z = Z = G + R(\cos \nu - \mu_1 \cos \gamma); \end{array}\right\} \quad \ldots\ldots\ldots\ldots\ldots (1)$$

and the equations of motion will be

$$M \frac{d^2 z}{dt^2} = G + R(\cos \nu - \mu_1 \cos \gamma), \quad \ldots\ldots\ldots\ldots\ldots\ldots (2)$$

$$\frac{d^2 \phi}{dt^2} = \frac{Yx - Xy}{M\rho^2}, \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

ρ being the radius of gyration.

We proceed to determine the value of the angles $\alpha, \beta, \gamma, \lambda, \mu, \nu$. Let the equations to the helix described by the point P be put under the form

$$x = r \cos \phi, \quad y = r \sin \phi, \quad z = kr\phi, \quad \ldots\ldots\ldots\ldots\ldots\ldots (4)$$

k being the tangent of the angle at which the helix is inclined to the plane of xy. Then

$$dx = -r \sin \phi d\phi, \quad dy = r \cos \phi d\phi, \quad dz = krd\phi,$$

$$ds = r\sqrt{1 + k^2} \,.\, d\phi,$$

and

$$\left.\begin{aligned}\cos\alpha &= \frac{dx}{ds} = \frac{-\sin\phi}{\sqrt{1+k^2}},\\ \cos\beta &= \frac{dy}{ds} = \frac{\cos\phi}{\sqrt{1+k^2}},\\ \cos\gamma &= \frac{dz}{ds} = \frac{k}{\sqrt{1+k^2}}.\end{aligned}\right\} \quad\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (5)$$

To determine the values of λ, μ, ν, we shall first seek the equation to the driving-surface of the groove. In the case under consideration, the surface is a well-known conoidal one, the "skew heliçoid," and is familiar to the eye as the under surface of a spiral staircase. It is generated by a straight line which, passing through the axis of z, always remains perpendicular to it, and meets the helix described by the point P. The equations to the director being given in (4), if x_1, y_1, z_1 be the current co-ordinates of the generator, its equations are

$$x_1 y - y_1 x = 0, \quad z_1 = z \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (6)$$

Hence

$$x = r\cos\frac{z_1}{kr}, \quad y = r\sin\frac{z_1}{kr};$$

and the equation to the surface is

$$y_1\cos\frac{z_1}{kr} - x_1\sin\frac{z_1}{kr} = 0,$$

or, dropping the suffixes,

$$y\cos\frac{z}{kr} - x\sin\frac{z}{kr} = 0 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (7)$$

Now λ, μ, ν being the angles which the normal to (7) makes with the axes,

$$\left.\begin{aligned}\cos\lambda &= \frac{\left(\frac{dF}{dx}\right)}{\left\{\left(\frac{dF}{dx}\right)^2 + \left(\frac{dF}{dy}\right)^2 + \left(\frac{dF}{dz}\right)^2\right\}^{\frac{1}{2}}},\\ \cos\mu &= \frac{\left(\frac{dF}{dy}\right)}{\left\{\left(\frac{dF}{dx}\right)^2 + \left(\frac{dF}{dy}\right)^2 + \left(\frac{dF}{dz}\right)^2\right\}^{\frac{1}{2}}},\\ \cos\nu &= \frac{\left(\frac{dF}{dz}\right)}{\left\{\left(\frac{dF}{dx}\right)^2 + \left(\frac{dF}{dy}\right)^2 + \left(\frac{dF}{dz}\right)^2\right\}^{\frac{1}{2}}}.\end{aligned}\right\} \quad\ldots\ldots\ldots\ldots\ldots \quad (8)$$

Now

$$\left(\frac{dF}{dx}\right) = -\sin\frac{z}{kr}, \qquad \left(\frac{dF}{dy}\right) = \cos\frac{z}{kr},$$

$$\left(\frac{dF}{dz}\right) = -\frac{1}{k}\left(\frac{x}{r}\cos\frac{z}{kr} + \frac{y}{r}\sin\frac{z}{kr}\right);$$

but since in the case we are now considering (x, y, z) is a point both in the surface given by equation (7) and in the directing helix, we have from (4),

$$\frac{x}{r} = \cos\phi = \cos\frac{z}{kr}, \qquad \frac{y}{r} = \sin\phi = \sin\frac{z}{kr};$$

$$\text{therefore} \quad \left(\frac{dF}{dz}\right) = -\frac{1}{k};$$

$$\text{and} \quad \left\{\left(\frac{dF}{dx}\right)^2 + \left(\frac{dF}{dy}\right)^2 + \left(\frac{dF}{dz}\right)^2\right\}^{\frac{1}{2}} = \frac{1}{k}\sqrt{1+k^2}.$$

Hence

$$\left.\begin{aligned} \cos\lambda &= -\frac{k\sin\phi}{\sqrt{1+k^2}}, \\ \cos\mu &= \frac{k\cos\phi}{\sqrt{1+k^2}}, \\ \cos\nu &= -\frac{1}{\sqrt{1+k^2}}. \end{aligned}\right\} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (9)$$

Now substituting the values of the direction cosines given in equations (5) and (9), in (1), (2), and (3), we have as the equations of motion,

$$M\frac{d^2z}{dt^2} = G - \frac{R}{\sqrt{1+k^2}}(\mu_1 k + 1), \quad \ldots\ldots\ldots\ldots \quad (10)$$

$$\frac{d^2\phi}{dt^2} = \frac{Rr}{\sqrt{1+k^2}} \cdot \frac{k - \mu_1}{M\rho^2}; \quad \ldots\ldots\ldots\ldots \quad (11)$$

and hence the normal pressure on the rib of the projectile,

$$R = \frac{M\rho^2}{r} \cdot \frac{\sqrt{1+k^2}}{k - \mu_1} \cdot \frac{d^2\phi}{dt^2}.$$

But if ϖ be the angular velocity of the projectile, and h be the pitch of the rifling, we have the following relation between the velocities of translation and rotation,

$$\varpi = \frac{d\phi}{dt} = \frac{2\pi}{h}v = \frac{2\pi}{h} \cdot \frac{dz}{dt}.$$

Hence

$$\frac{d^2\phi}{dt^2} = \frac{2\pi}{h} \cdot \frac{d^2z}{dt^2},$$

and

$$R = \frac{M\rho^2}{r} \cdot \frac{\sqrt{1+k^2}}{k-\mu_1} \cdot \frac{2\pi}{h} \cdot \frac{d^2z}{dt^2} \text{ ....} \quad (12)$$

Now substituting in this equation the value of $\frac{d^2z}{dt^2}$ derived from (10), we have

$$R = \frac{2\pi\rho^2}{rh} \cdot \frac{\sqrt{1+k^2}}{k-\mu_1} \left\{G - \frac{R}{\sqrt{1+k^2}}(\mu_1 k + 1)\right\},$$

or

$$\frac{R}{G} = \frac{2\pi\rho^2\sqrt{1+k^2}}{hr(k-\mu_1) + 2\pi\rho^2(\mu_1 k + 1)} \text{ ....} \quad (13)$$

And this equation gives the ratio between the pressures producing translation and rotation.

We now proceed to determine the increment of the gaseous pressure due to the resistance, &c. offered by the rifling to the forward motion of the shot. We shall imagine a smooth-bored gun to fire a shot of the same weight as that of the rifled gun. We shall further suppose that the two projectiles are delivered with the same velocity; and we wish to know, the same ballistic effect being produced by the two guns, what is the increased pressure which the rifled gun has had to sustain. Now the equation of motion in the case of the smooth-bored gun is

$$M\frac{d^2z}{dt^2} = G, \text{ ....} (14)$$

and in the case of the rifled gun,

$$M\frac{d^2z}{dt^2} = G' - \frac{R}{\sqrt{1+k^2}}(\mu_1 k + 1) \text{ ....} \quad (15)$$

Now if the velocity-increments in the two cases be taken as equal, we shall have from equations (14) and (15),

$$G' = G + \frac{R}{\sqrt{1+k^2}}(\mu_1 k + 1) \text{ ....} (16)$$

And the second term of the right-hand member of equation (16) represents the increment of pressure due to the rifling.

Let us now examine the pressures which subsist when a polygonal form of rifling is adopted; and we shall suppose the polygon to have n sides. The equations of motion given in equations (2) and (3) hold here as in the last case, and the values of α, β, γ given in (5) remain the same. The driving-surface is, however, different, being traced out by a straight line which always remains parallel to the plane of xy, meets the helix described by P, and touches the cylinder whose radius is $= r\cos\frac{\pi}{n}$ (see fig, 3, where PA

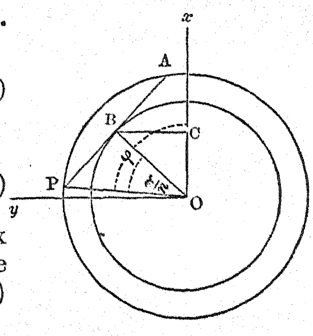
represents the generating line drawn from a point P of the helix to touch the cylinder BC). Now the equations to the helix being

$$x = r\cos\phi,\ y = r\sin\phi,\ z = kr\phi,\ \dots \quad (17)$$

while that to the cylinder is

$$x^2 + y^2 = \left(r\cos\frac{\pi}{n}\right)^2 = r_1^2 \text{ suppose,} \dots (18)$$

Fig. 3.



if we draw from the point P (x, y, z) of the helix a tangent in the plane $z = kr\phi$ to (18), the co-ordinates of the point of contact (see fig. 3) will be

$$\left.\begin{aligned} x_1 &= r_1\cos\left(\phi - \frac{\pi}{n}\right), \\ y_1 &= r_1\sin\left(\phi - \frac{\pi}{n}\right). \end{aligned}\right\} \dots\dots\dots\dots\dots\dots\dots\dots \quad (19)$$

Now, the equation to the tangent drawn through the point $x_1\, y_1$ of the circle $x^2 + y^2 = r_1^2$ is

$$xx_1 + yy_1 = r_1^2 \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots \quad (20)$$

And substituting in this equation the values of x_1 and y_1 derived from (19), we obtain as the equations of the generator,

$$xr_1\cos\left(\phi - \frac{\pi}{n}\right) + yr_1\sin\left(\phi - \frac{\pi}{n}\right) = r_1^2,\ z = kr\phi,\ \dots\dots\dots \quad (21)$$

and as the equation to the driving-surface,

$$x\cos\left(\frac{z}{kr} - \frac{\pi}{n}\right) + y\sin\left(\frac{z}{kr} - \frac{\pi}{n}\right) = r\cos\frac{\pi}{n} \dots\dots\dots\dots \quad (22)$$

Now

$$\left(\frac{dF}{dx}\right) = \cos\left(\frac{z}{kr} - \frac{\pi}{n}\right), \quad \left(\frac{dF}{dy}\right) = \sin\left(\frac{z}{kr} - \frac{\pi}{n}\right),$$

$$\left(\frac{dF}{dz}\right) = \frac{1}{k}\left\{\frac{y}{r}\cos\left(\frac{z}{kr} - \frac{\pi}{n}\right) - \frac{x}{r}\sin\left(\frac{z}{kr} - \frac{\pi}{n}\right)\right\};$$

or, since P, (x, y, z) is a point at once in the helix and the skew surface,

$$\left(\frac{dF}{dz}\right) = \frac{1}{k}\sin\frac{\pi}{n}.$$

Also

$$\left\{\left(\frac{dF}{dx}\right)^2 + \left(\frac{dF}{dy}\right)^2 + \left(\frac{dF}{dz}\right)^2\right\}^{\frac{1}{2}} = \frac{1}{k}\sqrt{k^2 + \left(\sin\frac{\pi}{n}\right)^2},$$

And substituting these values of $\left(\frac{dF}{dx}\right)$, &c. in (8), we have for the direction cosines at the point P,

$$\left.\begin{aligned}
\cos\lambda &= -\frac{k\cos\left(\frac{z}{kr}-\frac{\pi}{n}\right)}{\sqrt{k^2+\left(\sin\frac{\pi}{n}\right)^2}},\\
\cos\mu &= -\frac{k\sin\left(\frac{z}{kr}-\frac{\pi}{n}\right)}{\sqrt{k^2+\left(\sin\frac{\pi}{n}\right)^2}},\\
\cos\nu &= -\frac{\sin\frac{\pi}{n}}{\sqrt{k^2+\left(\sin\frac{\pi}{n}\right)^2}}.
\end{aligned}\right\}\quad\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (23)$$

And putting the values of α, β, γ, λ, μ, ν in the equations of motion (2) and (3), we have

$$M\frac{d^2z}{dt^2}=G-R\left\{\frac{\mu_1 k}{\sqrt{1+k^2}}+\frac{\sin\frac{\pi}{n}}{\sqrt{k^2+\left(\sin\frac{\pi}{n}\right)^2}}\right\}\quad\ldots\ldots\ldots (24)$$

$$\left.\begin{aligned}
\frac{d^2\phi}{dt^2} &= \frac{Rr}{M\rho^2}\cdot\left[\left\{\frac{k\cos\left(\frac{z}{kr}-\frac{\pi}{n}\right)}{\sqrt{k^2+\left(\sin\frac{\pi}{n}\right)^2}}-\frac{\mu_1\sin\frac{z}{kr}}{\sqrt{1+k^2}}\right\}\sin\frac{z}{kr}\right.\\
&\qquad\left.-\left\{\frac{\mu_1\cos\frac{z}{kr}}{\sqrt{1+k^2}}+\frac{k\sin\left(\frac{z}{kr}-\frac{\pi}{n}\right)}{\sqrt{k^2+\left(\sin\frac{\pi}{n}\right)^2}}\right\}\cos\frac{z}{kr}\right]\\
&= \frac{Rr}{M\rho^2}\cdot\left\{\frac{k\sin\frac{\pi}{n}}{\sqrt{k^2+\left(\sin\frac{\pi}{n}\right)^2}}-\frac{\mu_1}{\sqrt{1+k^2}}\right\}
\end{aligned}\right\}\quad\ldots\ldots (25)$$

Hence

$$R=\frac{M.\rho^2}{r.\left\{\frac{k\sin\frac{\pi}{n}}{\sqrt{k^2+\left(\sin\frac{\pi}{n}\right)^2}}-\frac{\mu_1}{\sqrt{1+k^2}}\right\}}\cdot\frac{d^2\phi}{dt^2}.$$

But

$$\frac{d^2\phi}{dt^2} = \frac{\pi r}{h} \cdot \frac{d^2 z}{dt^2};$$

and making the necessary substitutions, we obtain for the ratio between the forces producing rotation and translation,

$$\frac{R}{G} = \frac{2\pi\rho^2}{\frac{\mu_1}{\sqrt{1+k^2}}(2\pi\rho^2 k - rh) + \frac{\sin\frac{\pi}{n}}{\sqrt{k^2 + \left(\sin\frac{\pi}{n}\right)^2}}\left(2\pi\rho^2 \sin\frac{\pi}{n} + rhk\right)} \quad \ldots (26)$$

In precisely the same manner as in the former case, and on the same hypotheses, we may show that if G'' denote the gaseous pressure in a bore rifled on the system we are now considering, and G denote the gaseous pressure in a similar smooth-bored gun, we shall have

$$G'' = G + R\left\{\frac{\mu_1 k}{\sqrt{1+k^2}} + \frac{\sin\frac{\pi}{n}}{\sqrt{k^2 + \left(\sin\frac{\pi}{n}\right)^2}}\right\} \quad \ldots\ldots\ldots\ldots (27)$$

Hence if we have three guns of the same diameter of bore, viz. a smooth-bore gun, a rifled gun, the grooves of which are similar to those shown in fig. 1, and a third rifled polygonally, and if we suppose that the shot in each case are of the same weight, and further, that in each case the velocity-increments at the moment under consideration are equal, then the pressures upon the base of the shot will be as follow :—In the case of the

$$\left.\begin{array}{l} \text{Smooth-bored gun, pressure} = G; \\ \text{First rifled gun, pressure} = G + \dfrac{R}{\sqrt{1+k^2}}(\mu_1 k + 1); \\ \text{Polygonally-rifled gun, pressure} \\ \qquad = G + R\left\{\dfrac{\mu_1 k}{\sqrt{1+k^2}} + \dfrac{\sin\frac{\pi}{n}}{\sqrt{k^2 + \left(\sin\frac{\pi}{n}\right)^2}}\right\}. \end{array}\right\} \quad \ldots\ldots\ldots (28)$$

We shall now give examples of the cases we have been discussing to exhibit numerically the above results.

Let us suppose that two seven-inch guns are rifled—the first according to the method shown in fig. 1, with a pitch of one turn in 294 inches, the other octagonally, with a pitch of one turn in 130 inches. It is required to determine in each case the pressure on the driving-surface in terms of the pressure on the base of the shot. Now, in the first case, from (13),

$$\text{Pressure on driving surface} = \frac{2\pi\rho^2\sqrt{1+k^2}}{hr(k-\mu_1)+2\pi\rho^2(\mu_1 k+1)} \cdot G,$$

where

$$\pi = 3{\cdot}14159, \quad \rho = r\sqrt{\tfrac{1}{2}} = 2{\cdot}475, \quad k = 13{\cdot}3697, \quad h = 294,$$

$$r = 3{\cdot}5, \quad \mu_1 = {\cdot}1666,$$

whence we obtain

$$R = {\cdot}0375\, G \ldots\ldots\ldots\ldots\ldots\ldots \quad (29)$$

In the second case from (26),

$$\text{Pressure} = \frac{2\pi\rho^2}{\frac{\mu_1}{\sqrt{1+k^2}}(2\pi\rho^2 k - rh) + \frac{\sin\pi}{\sqrt{k^2+\left(\sin\frac{\pi}{n}\right)^2}}\left(2\pi\rho^2\sin\frac{\pi}{n} + rhk\right)} \cdot G,$$

where

$$\pi = 3{\cdot}14159,$$

$$\rho = \frac{1}{12}c^2 \cdot \frac{2+\cos\frac{2\pi}{n}}{1-\cos\frac{2\pi}{n}} = 2{\cdot}350 \ (c = \text{length of side of polygon}),$$

$$k = 5{\cdot}9117, \quad h = 130, \quad r = 3{\cdot}5, \quad n = 8, \quad \mu_1 = {\cdot}1666,$$

$$\frac{\pi}{n} = 22^\circ\ 33',$$

whence

$$R = {\cdot}1706\, G \ldots\ldots\ldots\ldots\ldots\ldots \quad (30)$$

That is, on the supposition of the same pressure on the base of the shot, the pressure on the driving-surface is in the latter case nearly five times as great as in the former, and is, in fact, no inconsiderable fraction of the propelling force.

Let us now compare the gaseous pressures on the base of shot of the same weight supposed to be fired from the guns above described, and from a smooth-bored gun. From equations (28) we have the pressure upon base of shot fired from

Smooth-bored gun........................$= G$,
First rifled gun..........................$= 1{\cdot}009\, G$,
Polygonal gun ....$= 1{\cdot}041\, G$.

In these calculations we have taken the coefficient friction $= \frac{1}{6}$. It is necessary, however, to observe that very little is known concerning the value of this constant at pressures so high as those with which we have here to do. It is evident that in the case of the contact of similar metals, when the point of seizure is approached, the coefficient of friction cannot be

considered independent of the pressure; and it is probable that when the rubbing surfaces of both projectile and groove (or other driving-surface) are of the same hard material, the coefficient of friction may be occasionally enormously increased.

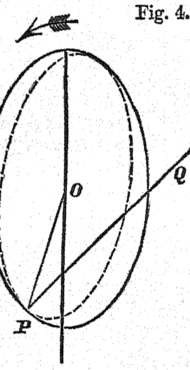
The resistance due to this cause might, under certain circumstances, be sufficient to ensure the destruction of the gun; and this view is to some extent corroborated by the occasional bursting of guns, the failure of which it is difficult to attribute to any other cause; and in the instances referred to, the recovered fragments of the shot were thought to exhibit decided appearances of seizure.

If in equation (26) we substitute δ for $\frac{\pi}{n}$, we shall have

$$\frac{R}{G}=\frac{2\pi\rho^2}{\frac{\mu_1}{\sqrt{1+k^2}}(2\pi\rho^2 k-rh)+\frac{\sin\delta}{\sqrt{k^2+(\sin\delta)^2}}(2\pi\rho^2\sin\delta+rhk)} \quad \text{... (31)}$$

And this equation will represent the ratio of the pressures R and G in any system of rifling, δ being the angle which the radius makes with the normal to the driving-surface. Thus in an elliptically-bored gun (see fig. 4), the angle OPQ represents the angle δ, and we obtain $\frac{R}{G}$ by substituting in (31) the value of this angle; by putting $\delta=90°$, we may derive equation (13) directly from (31).

Fig. 4.



We have not in this note entered into the question of the absolute pressures existing in the bores of ordnance of various natures, as the subject is too extensive and of too great importance to be disposed of within the limits of a short paper.

Artillerists acquainted with the subject will be able to form rough approximations to these pressures from the experiments made abroad with smooth-bored guns, with a view to the elucidation of this important question. It is much to be regretted that no experiments of the nature referred to have been attempted in England under Government auspices, as they are of a description which precludes their being satisfactorily made by private individuals, and as the information to be derived from them would be especially important in the case of rifled cannon, where so many new conditions are introduced into the problem as to render previous investigations of but little value.

We shall, however, in a future note endeavour to discuss this subject, making use of the data at present at our disposal.

ACCOUNT

OF

PRELIMINARY TRIAL OF A 600-pr. 13·3 in. M. L. WROUGHT-IRON, 10 GROOVED SHUNT ARMSTRONG RIFLE GUN, UNDER THE DIRECTION OF THE O. S. COMMITTEE, SHOEBURYNESS, 19TH NOVEMBER, 1863.

BY CAPTAIN E. J. BRUCE, R.A.

This gun was made at Elswick, Newcastle-on-Tyne, and had not been fired (even for proof) before the present trial.

THE dimensions of the gun are as follows:—

	ft.	in.
Length over all	15	3
Length behind trunnion centre	6	2·5
Length of bore	12	1·25
Diameter of bore	0	13·3
External diameter over breech	4	3·5
,, over trunnion hoop	4	5·5
,, at muzzle	1	9·5
Width over trunnion ends	6	2·5

The gun is built up of eight layers of coiled cylinders barrel inclusive, varying in thickness from 2 in. to 2·8 in. The pressure on the back of the bore is carried chiefly (as in all the Armstrong guns) by a breech piece, so called, forged solid, bored out, and shrunk on the barrel. The breech piece of this gun is 6 ft. 8¼ in. long, has an outside diameter of 2 ft. 6·3 in. and a section of 458 square inches. The section of coils operative to resist end thrust may be taken as about equal to 125 in. more, making 583 square inches in all to meet the strain upon 140″, the area of the bore. The barrel was made open right through, and the breech end is closed by a wrought-iron cylindrical plug fitted into the bore and backed up by a forged wrought-iron piece screwed into the breech piece, and faced with a steel disc.

The trunnion hoop is made from scrap iron forged under the hammer. It is 6 in. thick and 16·5 in. wide, and is shrunk on the sixth course of cylinders.

The trunnion hoop and breech piece forgings weighed before machining 4¾ tons and 8½ tons respectively.

The outer breech coil was made from a bar 5 in. deep × 4 in. wide in section, and 124 ft. long. This bar weighed 71 cwt. It was heated in one length, and wound on a drum by a machine at the mouth of the heating furnace. The coil was then welded under a 15 ton hammer. This is by far the largest coiled cylinder yet made.

The weight of the finished gun is 22 tons, 18 cwt.

The gun was built up to the 5th course, inclusive, in the manner ordinarily practised at Elswick, being turned in the lathe after each course was added, to the proper size for the next course; but the three outer courses were put on without moving the gun from the contracting pit, being accurately turned and bored to dimensions calculated to allow for the alterations due to the contracting process. This was an important step in the progress of manufacture of built up guns, because their size ceases to be limited by the power of machines when their various parts can be finished separately and then built up into the complete gun in one place by simple superposition.

The 600-pr. gun is rifled on Sir William Armstrong's shunt principle with 10 grooves, having a depth at muzzle of ·08″, and a twist of 1 turn in 65 diameters.

The projectiles are provided with brass studs ·85 in. diameter, flattened sideways to about ·65″, in ten rows of five or six each to run in the rifle grooves. The studs are fixed into the projectiles by being stamped into shallow undercut holes.

The segment shell carries 510 segments averaging 6 oz. each, packed as in the 12-pr. segment shell, but in two rows instead of in one. The bursting charge is 15 lbs.

The common shell is about 30 in. long, and carries a bursting charge of from 45 to 47 lbs. of powder.

The steel shell carries a bursting charge of 24 lbs.,* and is closed by a hollow cast-iron plug *in front*, so that on piercing plates the powder takes effect forward.

The 600-pr. gun was commenced in May, 1862, and delivered in March, 1863.†

THIS gun was mounted on a garrison sliding carriage weighing 54 cwt., with special platform weighing 75 cwt., having a slope of 3½°, and with raised iron racer 18 ft. 9 in. long to the stop.

The rifle projectiles on the ground were as follows:—

A. Cast-iron solid shot, with hollow conoidal head. Length 25·1 in.; mean weight 510 lbs.
B. Cast-iron solid shot, flat-headed. Length ; mean weight‡
C. Cast-iron common shell, conoidal head. Length 30·5 in.; mean weight 556 lbs.; capacity 42·5 lbs.
D. Steel shell, with cast-iron hollow round head or cap. Length of body 19·7; mean weight 588 lbs.; capacity 16 lbs.§

All these projectiles were fitted with soft gun metal studs to take the rifling.

There were also spherical cast-iron and steel shot, diameter 13·235, weight respectively 304 lbs. and 342 lbs.; of these *one* cast-iron shot was fired at the end of the day.

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* The powder being driving with setter and mallet, and a mixture used of F.G. and L.G. powder—one part F. G. to three parts L. G.

† For the foregoing particulars of construction and dimensions, I am indebted to G. W. Rendel, Esq.

‡ Not known.

§ Filled with L. G. powder well shaken down in the common way.

Of the rifle projectiles, those marked A and C only were fired on this occasion—the former with a charge of 70 lbs., the latter with 60 lbs. The velocities (up to 5° elevation) were taken by Lieut. Noble, R.A., with Navez's electro-ballistic apparatus, at two points—the first at 120 ft. from the muzzle, and again at a distance of 420 ft., i.e. 300 ft. between the screens. The latter observations are omitted as there is reason to believe that the pendulum of the second instrument was caused to drop by the shock of the discharge before the wires were severed by the passage of the shot.

The cartridge of 70 lbs. measured in length, before entering in the bore 25 in., when set home 22 in. A seam was run down the cartridge of 60 lbs., to make it the same length as the cartridge of 70 lbs.

The gun was served by one non-commissioned officer and twenty men.

The shot was laid in a metal cradle or "bearer," with grooves corresponding to the studs, and (when hooked on to the two supports at the muzzle) formed a continuation of the rifling of the gun, guiding the shot to enter true. The bearer was greased before every round.

An 18 ft. gyn, with luff tackle, was used to raise the bearer and shot to the height required to hook on, the shot was then pushed off the "bearer" into the bore, and rammed home.

One man brought up the cartridge, four the shot.

When sponging out dry, four men were enough to ram home the cartridge; after washing out, six were required.

Four men rammed home the shot easily.

The gun was traversed (on a raised iron racer) with treble and double block tackle; six men on each tackle ran the gun up after firing. Six to each truck lever to bear down, three to run up.

There was difficulty in elevating (in the ordinary way) in spite of $8\frac{1}{2}$ cwt. preponderance, owing to friction on trunnion holes. These were oiled, and a small hydraulic lifting jack (12 tons) applied below the muzzle, raised it easily; later, a double coil of rope was passed round the muzzle, and the muzzle raised more rapidly by means of the windlass and tackle of the gyn.

The elevations were given with the quadrant.

The report was less loud than might be expected; an officer stood within 40 ft. slightly to the right-rear, without feeling inconvenience from the shock.

Generally the shot ricocheted straight—four to six long bounds, then a series of lesser ones lost in distance. The hollow head appeared to break up generally on first or second graze on the water.

The time between shots, towards the end of the firing, was (with the incomplete appliances of a first experiment) ten minutes.

The gun was carefully examined, externally, after every round—internally, with lamp and searcher, after first and last rounds. A slight flaw, at 10 in. from the muzzle (known before firing), was not increased, and is understood to be the place where two lengths of coil are joined: the defect is, apparently, only superficial.

The bore had expanded a little at its junction with the plug, and is slightly oval at that place.

At the first discharge the B tube was set back the slightest perceptible amount from the muzzle: after this there was no sign of movement of parts.

Number of round.	Nature.	Projectile. Length.	Projectile. Diameter.	Projectile. Weight.	Projectile. Form.	Charge in lbs.	Range in yds. Actual.	Range in yds. Mean.	Elevation.	Deviation in ft. Right.	Deviation in ft. Left.	Recoil.	Time of flight.	Velocity at 120 ft.	Remarks.
		in.	in.	lbs.					°			ft.	′ ″		
1	C.I.*	25·1	13·25	509·0	A	70	740		1	...	3	8·5	1·8	1220	Compressor hard over, except where otherwise stated.
2	„	„	„	511·25	„	„	785	771	„	...	1	9·25	1·9	1266	
3	„	„	„	509·0	„	„	789		„	on	line	9·2	2·0	1257	
4	„	„	„	513·0	„	„	1160		2	...	4	10·7	3·2	1255	No compressor.
5	„	„	„	512·5	„	„	1148	1164	„	...	1	8·75	„	1258	
6	„	„	„	516·5	„	„	1184		„	on	line	9·0	„	1247	Shot jammed from fouling; some time spent in ramming home. After this, washed out, every round.
7	„	„	„	516·75	„	„	2400		5	12	...	„	6·7	...	
8	„	„	„	509·5	„	„	2338	2349	„	...	1	9·9	6·6	...	No compressor.
9	„	„	„	511·5	„	„	2308		„	on	line	9·7	„	...	do do
10	„	„	„	510·25	„	„	4080		10	6	...	7·6	12·5	...	No ricochet.
11	„	„	„	513·25	„	„	4176	4148	„	on	line	8·0	12·6	...	
12	„	„	„	507·25	„	„	4187		„	...	12	8·25	„	...	
13	C.I.†	30·5	„	595·81	C	60	1880	1889	5	...	6	8·5	6·0	...	Ricocheted, swerving to right considerably.
14	„	„	„	601·31	„	„	1898		„	...	11	8·75	6·1	...	Ricocheted to left.
15	„	„	„	599·31	„	„	...	...	„	...	...	11·2	6·3	...	Owing to increased recoil and time of flight, a doubt was cast on the correctness of the 60 lbs. charge, but those responsible maintained that there was no increase of powder.
16	C.I.*	...	13·2	304·75	S‡	70	about 960	...	1	...	...	6·25	2·2	1576	The loss of velocity in passing over the interval between the screens (300 ft.) was 110 ft. The rifle projectile, in passing over the same distance lost about 25 ft.

* Cast-iron solid shot. † Cast-iron common shell. ‡ Spherical.

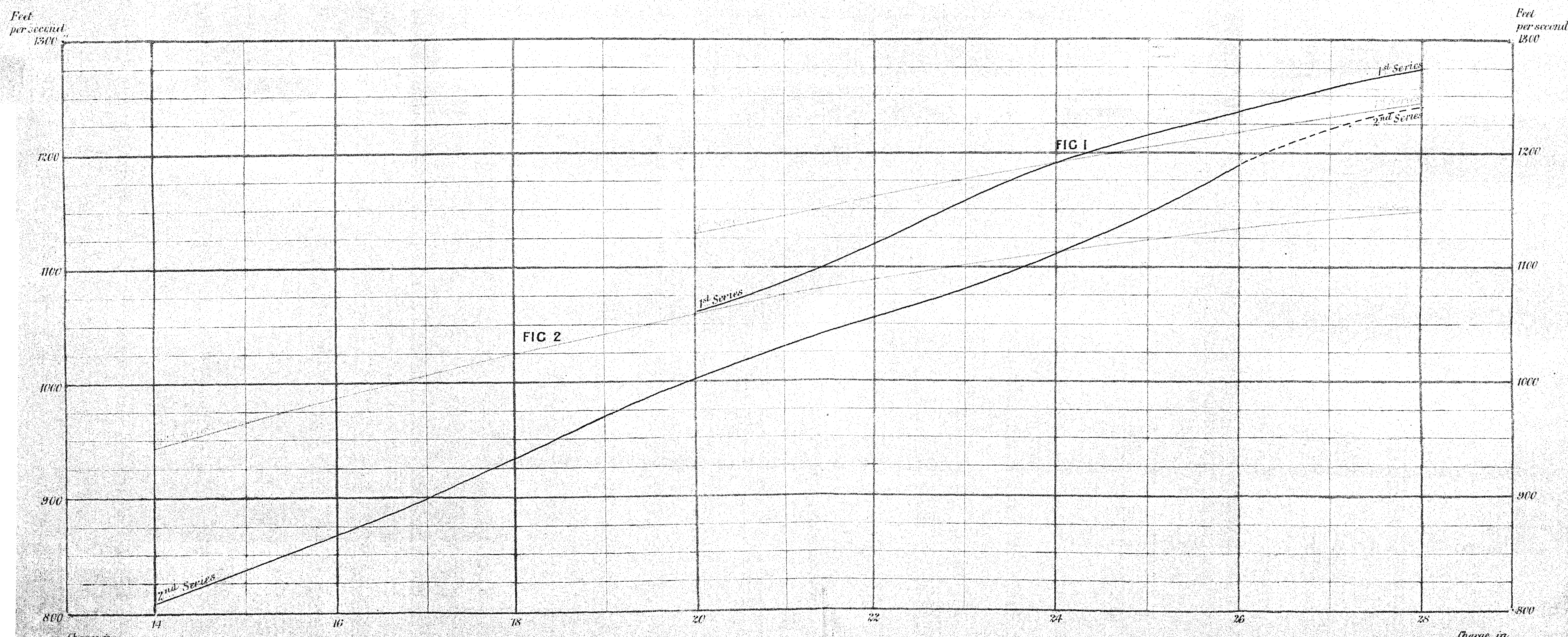
INDEX.

DIAGRAM SHEWING THE INITIAL VELOCITILS OF A 12 P.R ARMSTRONG PROJECTILE

AS A FUNCTION OF THE WEIGHT OF THE CHARGE.

NOTE_ Black lines shew observed Velocities.

Red lines shew computed Velocities.



Day & Son Lith.rs to the Queen

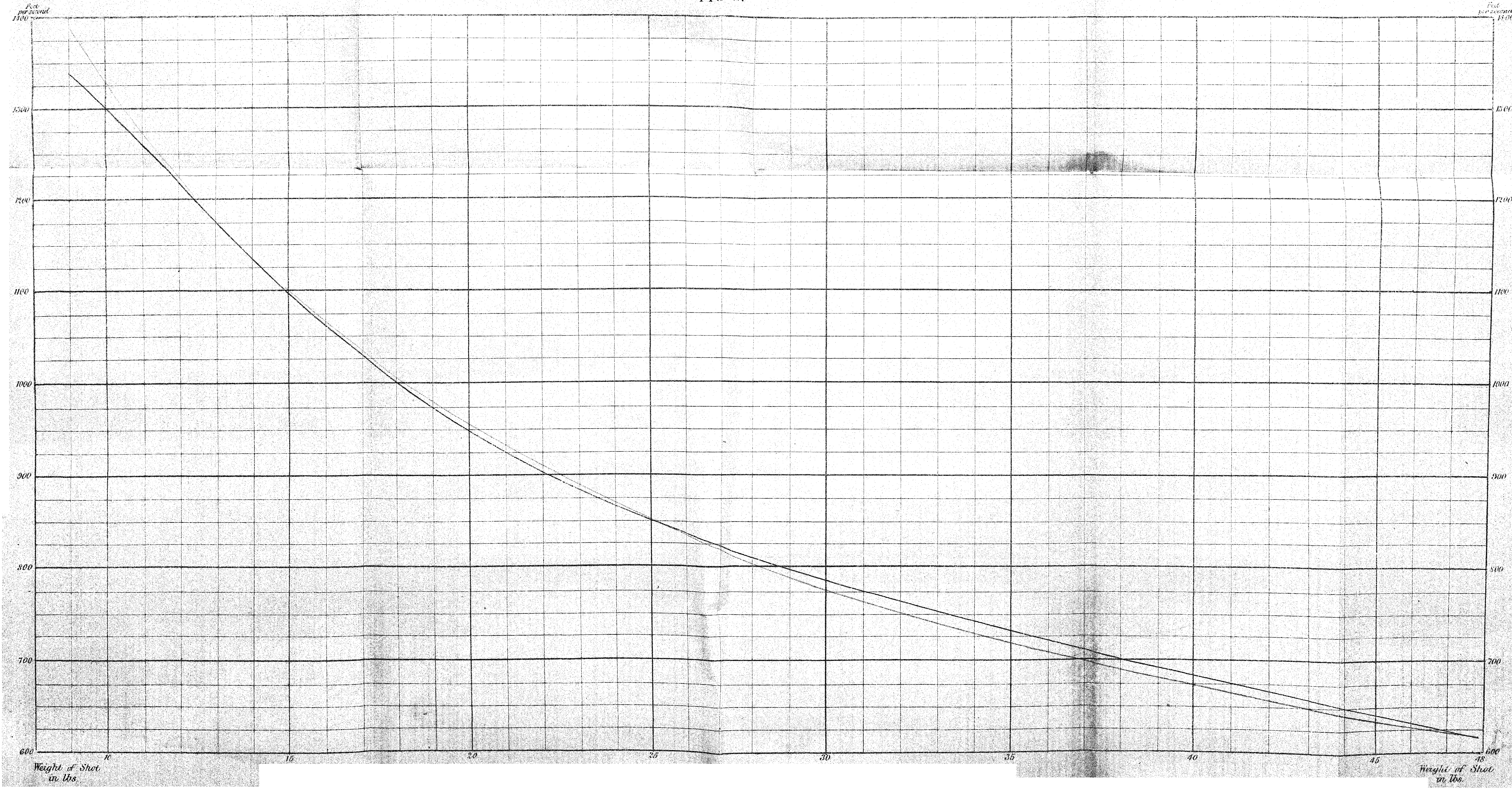
DIAGRAM SHEWING THE INITIAL VELOCITIES OF PROJECTILES FIRED FROM A 12 P^R. ARMSTRONG GUN

AS A FUNCTION OF THE WEIGHT OF THE SHOT.

NOTE_ Black lines shew observed Velocities.

Red lines shew computed Velocities

FIG 3.

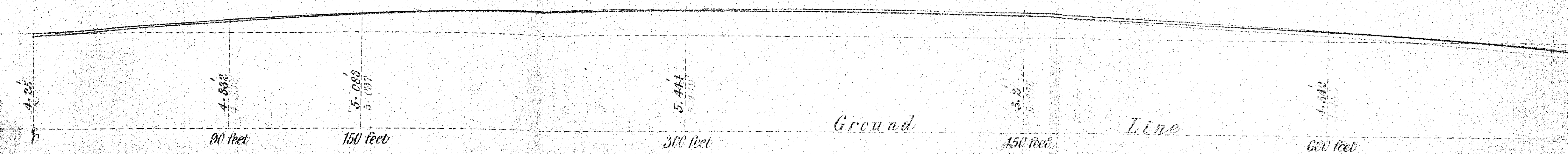


TRAJECTORIES OF 12 PR. ARMSTRONG GUN No. 224 FIRED WITH SERVICE

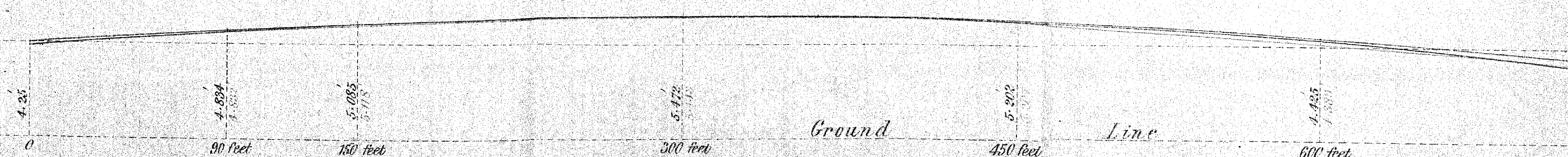
From Experimts made Septr. 10th & 15th 1860.

Scale of scissae 50 feet to an inch.
„ „dinates 10 times that of Abscissa.

Mean of 6 rounds.
Initial Velocity 1197·5 feet per second.
Angle of departure 0° - 25' - 4·4".
Range 938 feet.
Gun laid Point Blank, Angle of Elevation 0' 0"
Height of Axis of Gun 4·25 feet.



Mean of 5 rounds.
Initial Velocity 1179·8 feet per second.
Angle of departure 0° 25 - 55"
Range 897 feet.
Gun laid Point Blank, Angle of Elevation 0' 0"
Height of Axis of Gun 4·25 feet.



[CONFIDENTIAL.]

ACCOUNT

OF

EXPERIMENTS CARRIED ON AT NEWHAVEN, SUSSEX, IN AUGUST AND SEPTEMBER, 1863, UNDER THE DIRECTION OF THE ORDNANCE SELECT COMMITTEE.

By Lieut. CHARLES STEWART, R.A.

SPECIAL PAPER

The distribution of which is expressly limited to Officers of the Royal Artillery.

The chief objects of these experiments were, first, to discover the penetration into earth of the various projectiles fired from the following guns, viz.: the 110-pr., 70-pr., 40-pr., 20-pr., and 12-pr. Armstrong guns, and the 68-pr., 10-inch, 8-inch, and 32-pr. smooth-bored guns; and secondly, to test the various kinds of fuzes which have been proposed during the last year or two.

The battery was situated on a small plateau about half a mile beyond and considerably above the town of Newhaven. The butts consisted of, first, a parapet of made earth ten feet high and twenty-five feet thick (measured on the superior slope) and distant from the battery about 1060 yards, and secondly, of a natural mound of earth known as the Castle Hill, and some fifty yards in rear of the made parapet.

The artificial butt was composed of sand and clay; the natural one chiefly of compact stony loam, but in some parts of hard natural concrete.

These butts are about 180 feet, and the site of the battery about 230 feet above the sea level.

In the following sketch of the experiments each gun is taken separately, a short account being given of the practice from each, and the effect of the projectiles on the butts.

The penetrations given, having been merely roughly calculated on the spot, do not pretend to give more than a general idea. For them as well as for much other information I am indebted to the officers of the Royal Engineers under whose direction the projectiles were dug out of the butts.

110-pr. Armstrong Gun.

110-pr. Armstrong gun of 81 cwt. mounted on naval sliding carriage.

The practice from this gun commenced on the 11th August with firing solid shot at the artificial butt, the service charge of 12 lbs. being used and the elevation being 2° 34′. The following day the same projectiles were fired at the natural butt with the same charge and an elevation of 2° 40′.

The average penetration was found to be, into the made earth, about 20 feet, and into the natural, about 9½ feet.

On the 12th, blind shells, filled with sand, were fired into the artificial, and on the 13th into the natural butt, the charge and elevations being the same as with solid shot; the penetration averaged about 16 feet into the artificial earth, and about 10½ feet into the natural.

On the 14th, twenty-two live shells were fired at the natural butt with an elevation of 2° 40′, the service charge of 12 lbs., and the bursting charge of 8 lbs.

The service pillar percussion fuze was used for the first ten rounds, of these three burst in the butt, one fell short and burst, and the other six burst at the muzzle of the gun. Six rounds were then fired with the naval percussion fuze of which two burst satisfactorily, and four were blind. These were followed by six rounds of Armstrong's "more sensitive" pillar fuze, of which five burst in the butt, and one at the muzzle.

On the 1st September practice with live common shell from this gun was recommenced. As it seemed not improbable that the bursting of the shells at the muzzle during the former practice arose from there being a vacant space in the powder chamber, the cartridge not filling it by some inches, wooden bottoms 2¾ inches thick were provided to be put in at the back of the shell to fill up this space. The elevation and charge were the same as before. The first shell burst at the muzzle; a wooden disc half an inch thick was then put in, in addition to the wooden bottom, and six rounds fired of which four burst in the butt and two burst at the muzzle, the service pillar fuze being used. Ten rounds were then fired, the charge being reduced to 9 lbs. and the elevation increased to about 3° 30′, with the same fuze as before, of these five burst in the butt, and five did not burst at all.

On the 2nd September this gun was fired with a reduced charge of 10 lbs.; an increase of 1 lb. on the reduced charge of the preceding day. The natural butt was still the one aimed at, the elevation varying from 3° 18′ to 3° 24′. Ten rounds were fired with the service pillar fuze (Royal Laboratory) of which five burst satisfactorily, four were blind, and one burst at the muzzle. The range with this charge was somewhat uncertain, and the shells appeared to move very unsteadily.

Ten rounds were then fired with the full charge of 12 lbs. and an elevation of 2° 40′—the fuze being the service pillar (Elswick Ordnance Company). All of these burst satisfactorily in the butt. Afterwards five rounds were fired with the 9 lbs. charge, an elevation of 2° 32′ and the same fuze, all of which also burst in the butt.

On the 3rd September a few rounds of common shell with the ordinary bursting charge of 8 lbs. were fired from the 110-pr. gun with the charge reduced to 2 lbs. 14 oz., and the elevation increased to 15° 15′ for the purpose of pitching the shells over the artificial butt or parapet, to ascertain their effect on some wooden guns placed in the ditch in rear. After three rounds of solid shot fired to obtain the necessary elevation, two rounds of shell with the service pillar fuze were fired, but both were blind. Two rounds were then fired with the "more sensitive" pillar fuze which were also blind; these were followed by two rounds with the screw percussion fuze and with the same result, neither of the shells bursting. This experiment was therefore unsatisfactory.

On the same day nine rounds were fired at the natural butt with the half-charge of 6 lbs. and an average elevation of 5° 50′. Seven of the shells were fired with the service pillar fuze and all were blind; the other two were fired with the "more sensitive" pillar fuze, and both burst in the butt. The gun was then directed against the artificial butt, and six rounds fired with the "more sensitive" fuze, of which four burst.

The service charge of 12 lbs. was then resumed and fifteen rounds fired against the artificial butt, the elevation being 2° 31′. The first shell was fired with a "more sensitive" pillar fuze, and burst properly. It was followed by five rounds with the service pillar (Moorsom's composition) of which only two shells burst; the remaining nine were fired with the sensitive fuze and five of them burst in the butt, and one about fifty yards from the muzzle, the others being blind.

On the 4th September seventy-six shells were fired from this gun at the artificial butt for the purpose of cutting a passage through it. Thirty were fired with the service pillar (Moorsom's composition), nine with the screw percussion, nine with the "more sensitive" pillar, and the remainder with the service pillar (Elswick). The greater part of these burst in the butt, although some were blind, and two or three burst at the muzzle. The experiment was most satisfactory as these shells, with a smaller number of 70-pr. shells, cut a deep passage right through the parapet; clearly showing the terribly destructive effect of shells from the heavier natures of Armstrong guns against earthworks.

The practice of this gun was concluded by firing a few shells at, and demolishing a strong splinter-proof, used during the experiments by the party at the butts.

The premature explosions of the shells from this gun appear to be caused by the fuzes not being able to stand the shock they receive when the projectile enters the rifling of the piece, a shock distinct from that which the shell receives immediately on the explosion of the powder. The satisfactory practice however made by this gun during the latter part of the experiments serves to show that premature explosions are not so likely to take place as might be supposed from the earlier part of the practice, still there seems always to be, with a serviceable charge, considerable danger of the shells bursting prematurely.

The craters formed by the explosion of the 110-pr. shells were very large, and an immense quantity of earth was dislodged and loosened on each occasion.

70-pr. Armstrong Gun.

70-pr. Armstrong wedge-gun of 61 cwt., mounted on a garrison carriage.

On the 1st September solid shot were fired from this gun with a charge of 9 lbs. at the artificial butt, the elevation varying from 2° 10′ to 2° 20′, and also at the natural butt, the elevation being 2° 28′.

The penetration into the artificial butt was about 15 ft., and into the natural about 7 ft. On the same day three live common shell were fired at the natural butt with the same charge as before, an elevation of 2° 30′ and the service pillar fuze. All three burst in the butt, producing large and well-formed craters.

On the 3rd September twelve common shell were fired at the artificial butt with the same charge and an elevation of 2° 20′, Pettman's naval fuze being used. Eight of the shells burst in the butt, the other four being blind. On the 4th September fifteen shells were fired at the artificial butt to assist the 110-pr. in cutting through it. Most of the shells burst in the butt, and their effect was very destructive.

The bursting charge for these shells was 4¾ lbs.

40-pr. Armstrong Gun.

40-pr. Armstrong gun of 33 cwt. mounted on travelling carriage.

On the 11th August solid shot were fired at the artificial, and on the 12th at the natural butt with the service charge of 5 lbs., the elevations being respectively 2° and 2° 8′. The average penetration into the artificial butt was about 14½ ft., and about 7 ft. into the natural butt.

On the 12th, blind shell filled with sand were also fired at the artificial butt with an elevation of 2° 14′, the penetration being about 11½ ft.; on the 13th, the same projectiles were fired into the natural butt with an elevation of 2° 12′, and the penetration was found to be about 7 ft.

On the 14th, live shells were fired with the service pillar fuze, Armstrong's "more sensitive" pillar fuze, and the naval percussion fuze, the elevation being 2° 10′. Eleven rounds were fired with the first named fuze, six at the natural and five at the artificial butt, all of which burst. Five rounds were fired at natural earth with the "more sensitive" pillar fuze which also all burst satisfactorily. Eight rounds were then fired with the naval percussion fuze, of which six burst in the butt, the other two being blind.

On the 2nd of September, after two or three solid shot had been fired to ascertain the proper elevation, ten live common shell were fired with a small charge of 1¼ lbs., and bursting charge of 2½ lbs., for the purpose of throwing shells over the artificial butt into the cutting behind it. The elevation varied from 12° 5′ to 13°. The first shell had a service pillar fuze but did not burst; four shells were then fired with the sensitive pillar fuze all of which were blind. The other five were fired with the screw percussion fuze (naval thread); only two of the shells burst. On the 3rd September three rounds were fired with the same elevation and charge, with Pettman's sea service fuzes, which were all blind.

The result therfore of this experiment was, as in the similar one with the 110-pr. gun, very unsatisfactory.

On the 3rd, six shells were also fired at the natural butt with half charge, $2\frac{1}{2}$ lbs., and an elevation of 5°, the bursting charge being as before $2\frac{1}{2}$ lbs.; the first three shells, of which two burst, were fired with the service pillar fuze (Elswick); and the other three, which all burst, with the service pillar (Moorsom's composition). Eight rounds were then fired with the same charges and elevation of 4° 50′ at the artificial butt. Five of these had the sensitive pillar fuze, and four of the shells burst; the other three were fired with the service pillar (Moorsom), and only one burst.

On the 4th September fifty-eight shells were fired from the 40-pr. at the artificial butt with an elevation varying from 2° 5′ to 2° 25′; the service charge being used. The fuzes were the service pillar (Moorsom's composition), the "more sensitive" pillar, and the screw percussion.

The majority of these shells burst in the butt, but without making much impression; the craters formed being insignificant, and the amount of earth displaced too small to cause much destructive effect.

20-pr. Armstrong Gun.

20-pr. Armstrong gun of $16\frac{1}{2}$ cwt., mounted on travelling carriage.

On the 11th August solid shot were fired from this gun at the artificial butt, and on the 12th at the natural, the elevation being respectively about 2° 28′ and 2° 35′, and the service charge of 2 lbs. 8 oz., used in both cases. The penetration into the artificial butt was about 10 ft. and into the natural about $4\frac{1}{2}$ ft.

Blind shell were fired from this gun on the 12th and 13th, the elevation in firing at the artificial butt being 2° 35′, and the penetration about 10 ft., at the natural butt the elevation was 2° 43′ and the penetration about 7 ft.

On the 4th, live shell were fired with the service pillar fuze and an elevation of 2° 36′ at the natural butt, and out of six rounds five burst satisfactorily.

On the 4th September fifteen rounds of shells were fired at the artificial butt with the service charge and the service pillar fuze (Moorsom's composition). A considerable number of these shells did not burst. The craters formed by the explosion of the shells which did burst were naturally very small, and the same observations which have been made with respect to 40-pr. shells apply to them.

12-pr. Armstrong Gun.

12-pr. Armstrong gun of $8\frac{1}{2}$ cwt., mounted on travelling carriage.

On the 11th August segment shells, filled with sand, were fired from the 12-pr. with the service charge of 1 lb. 8 oz., and elevation of from 2° 4′ to 2° 6′. The following day the same projectiles were fired at the natural butt with the same charge and an elevation of 2° 10′. The whole of the shells broke up in the earth, therefore it was impossible from the above practice to decide the penetration.

It may here be stated that the solid shot of the Armstrong guns were found in the butts in every possible position, but as a rule with the point slightly inclined to the right. Some of the shot were found standing on end, some quite horizontal, and one or two must have turned right over, being found with their points towards the rear.

The fuzes were extracted from two Armstrong shells, a 110-pr. and a 40-pr. found in the butts, which had not exploded. In both cases the volume of the powder was found to be decreased by at least a third of its bulk owing to its having become mealed and caked together towards the bottom of the shell. This appears to account for the fact that an Armstrong shell penetrates further before bursting than a common shell from a smooth-bored gun as its shape enables the powder to become more caked, and consequently, subject to slower ignition than that in a spherical shell.

68-pr. Gun.

68-pr. gun of 95 cwt., mounted on naval sliding carriage.

On the 11th August, solid shot were fired with the service charge of 16 lbs., and elevation varying from $1\frac{7}{8}°$ to $2\frac{1}{8}°$ at the artificial butt; the penetration was found to be 15 ft.

On the 12th, solid shot were fired at the natural earth, with the same charge, the elevation varying from $2\frac{1}{4}°$ to $2\frac{1}{2}°$. The penetration was found to be about 12 ft. into the softer part of the natural butt, and rather more than half that amount into the hard concrete.

Blind shell were fired at both butts on the 12th and 13th; at the artificial butt with an elevation of $1\frac{3}{4}°$ and penetration of about 8 ft.; at the natural butt the elevation was $1\frac{7}{8}°$, and the penetration about 6 ft.

On the 2nd September, eight rounds of shell were fired at the natural butt, the charge being as before 16 lbs., the bursting charge 2 lbs. 4 oz. and the elevation 2°. Pettman's land service fuze was used, and out of the eight rounds, five shells burst satisfactorily.

On the 3rd September, eleven rounds of shell were fired with the same charges and fuze at the artificial earthwork, the elevation being $1\frac{7}{8}°$; seven of the shells burst, the other four being blind.

The craters formed by these shell were small in comparison with those formed by the 110-pr. Armstrong and 70-pr. Armstrong shells, nor was the amount of earth displaced nearly so great.

The difference between the effect of the explosion of the 68-pr. shells and those of the heavier natures of Armstrong's is evidently caused by the fact that the latter penetrate much further into the earth before bursting than the former, as explained above.

10-in. Gun.

10-in. gun of 85 cwt., mounted on naval sliding carriage.

On the 1st September blind shell, filled with sand, were fired at both the artificial and natural butts with the service charge of 12 lbs. In firing at the artificial butt the elevation was $2\frac{7}{8}°$ and the penetration about $11\frac{1}{2}$ ft.; at the natural butt the elevation was $3\frac{1}{8}°$ and the penetration about 4 ft.

On the 4th September, six shells were fired at the artificial butt with the service charge of 12 lbs.; a bursting charge of $6\frac{1}{4}$ lbs., and elevation of $2\frac{3}{4}°$. Pettman's land service percussion fuze was used. Of the six shells, only two burst.

8-in. Gun.

Eight-inch gun of 52 cwt., mounted on travelling carriage.

On the 12th August, blind shell filled with sand were fired at the artificial butt with the service charge of 8 lbs. and elevation of $2\frac{3}{4}°$, the penetration averaged 11 ft.

On the 13th, the same projectile was fired at the natural butt with the same charge, and an elevation of 3°; the penetration was only about 4 ft.

On the 1st September, seven live shell were fired at the natural butt with Pettman's land service fuze—all of which were blind. The elevation varied from 3° to $3\frac{1}{4}°$, and the same charge as before was used.

32-pr. Gun.

32-pr. gun of 50 cwt., mounted on travelling carriage.

On the 11th August, solid shot were fired from this gun at the artificial butt with the service charge of 8 lbs., the elevation being $2\frac{1}{8}°$ for most of the rounds. The penetration was about $12\frac{1}{2}$ ft.

On the 12th, solid shot were fired at the natural butt with the same charge, and an elevation of from $2\frac{1}{4}°$ to $2\frac{3}{8}°$. The average penetration was found to be not more than about 4 ft.

On the same day, blind shell were fired at the artificial butt, and on the 13th at the natural, with the same charges; the elevations being respectively $2\frac{1}{8}°$ and $2\frac{1}{4}°$, and the penetrations about 10 ft. and about 3 ft.

On the 1st September, eleven common shells were fired at the natural butt with Pettman's land service fuze; of these eight burst, the elevation varied from $2\frac{1}{4}°$ to $2\frac{1}{2}°$, and the service charge of 8 lbs. was used as before. The craters formed by the bursting of these shells were small, and the damage done inconsiderable.

Camp, Newhaven,
9th Sept., 1863.

Date of issue.	Return.	Date of issue.	Return.